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DIGITAL COMPUTER SOLUTIONS OF AMIDSHIP STRUCTURAL DESIGN PROBLEMS

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DIGITAL COMPUTER SOLUTIONS OF AMIDSHIP STRUCTURAL DESIGN PROBLEMS

by

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B.S., U.S. Naval Academy, 1954

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

FOR THE DEGREE OF

NAVAL ENGINEER

at the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

June, 1960

DIGITAL COMPUTER SOLUTIONS OF AMIDSHIP STRUCTURAL DESIGN PROBLEMS

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Submitted to the Department of Naval Architecture and Marine Engineering on May 21, 1960, in partial fulfillment of the requirements for the degree of Naval Engineer.

This work was done in part at the M.I.T. Computation Center, Cambridge, Massachusetts.

ABSTRACT

This thesis describes the programming of amidship structural design procedures for the IBM-704 computer.

Two problems, the selection of scantlings and plating for the amidships portion of a ship's hull and the design of a transverse web frame are programmed for a digital computer. A detailed explanation of the programs and a brief discussion of the methods of approach for adapting these design procedures to a digital computer are included.

Using rather simple engineering criteria, these programs essentially carry out the design procedures for the amidship's structure. The inputs are those forces, moments, dimensions and material characteristics which are either known or can be readily determined by the user. The information resulting from these programs is given in a convenient form. The programs have been written in such a manner that they may be easily followed and altered.

It is strongly emphasized that these programs are written with a factor of safety of 1.0 on the yield strength of the material. By suitably selecting the input information, any reasonable factor of safety may be obtained.

Conclusions:

a. The results of experiments regarding structural components can be readily incorporated into programs such as those contained in this thesis.

b. Digital computers can be used to solve extremely complex structural problems.

c. In general, the limitations imposed by the computer on a problem are less restrictive than those imposed by manual methods.

Recommendations:

a. The second program, that for the design of a transverse web frame is not working in all respects. The difficulties involved with this program are described in the main body of the thesis. These problems must be solved before this program can be considered useful.

b. The programs in this thesis should be expanded to include the best engineering knowledge and theory available.

c. Investigations should be made to adapt this approach to designing a grillage network similar to that of ref. 8.

Thesis Supervisor: J. Harvey Evans
Title: Associate Professor of Naval Architecture

ACKNOWLEDGEMENTS

The author is indebted to Professor J. Harvey Evans of the Naval Architecture and Marine Engineering Department, Massachusetts Institute of Technology, for his considerable interest, advice and guidance; to Mr. J. E. Kerwin of the same department for his great interest and assistance in programming the problems; to the various members of the Computation Center, Massachusetts Institute of Technology, for their patience, understanding and cooperation; to Mrs. Phyllis Sykes for her skill in preparing the thesis in its final form; and to my wife Barbara, whose patience and understanding leaves me forever thankful.

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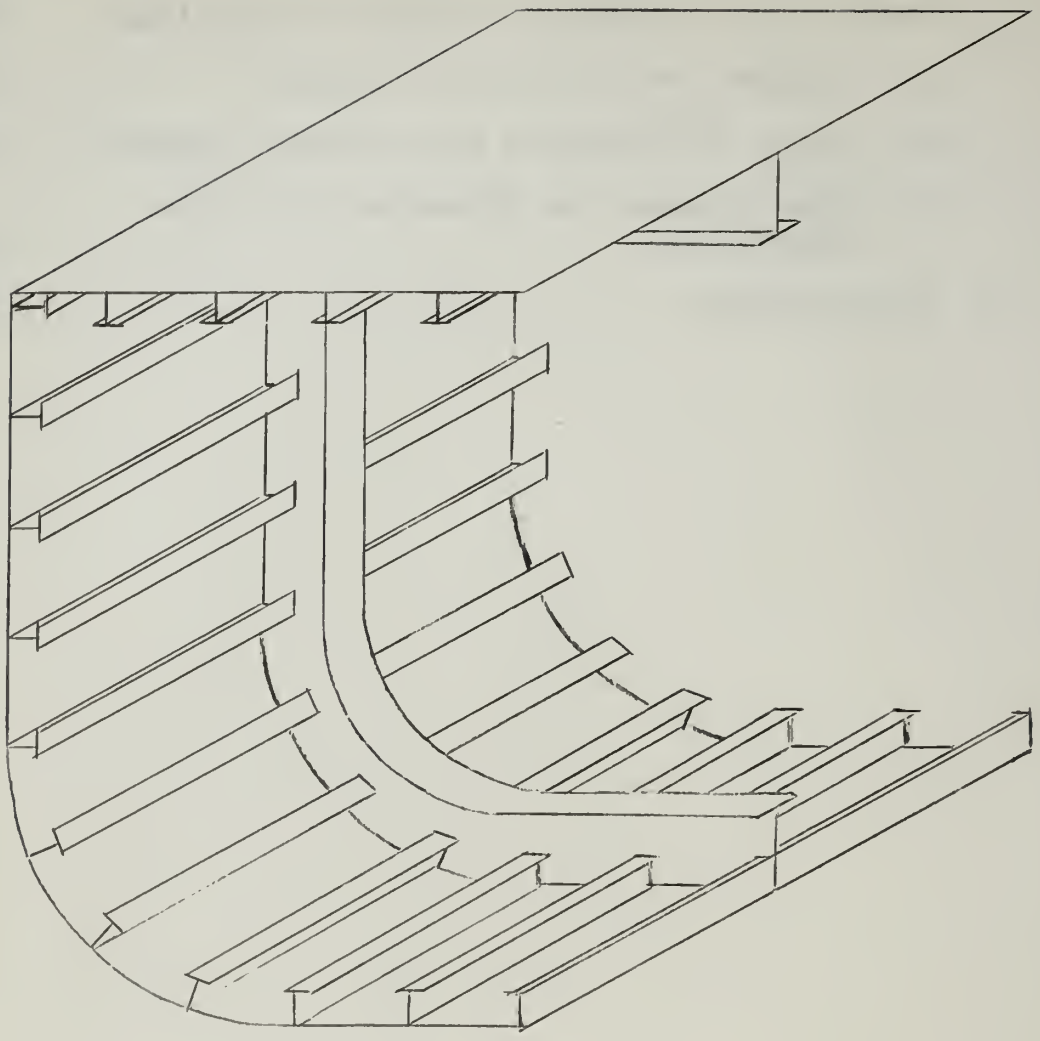


FIGURE 1

View of Structural Components of a Destroyer Type Hull

I. INTRODUCTION

The purpose of this work is to write computer programs which will select component members for a destroyer type hull such as that shown in Figure 1. This investigation has been divided into three parts, the first two of which are incorporated into this thesis:

(1) Write a computer program which will select scantlings and plating for an amidship's section of prescribed dimensions under the influence of bending moments and hydrostatic forces.

(2) Write a computer program which will size the web frame for the amidships section under the influence of internal and external forces.

(3) Review and analyze available engineering criteria and change the above programs in order that the design calculations may be carried out as accurately as possible.

In writing this thesis, knowledge of programming for the IBM 704 digital computer is assumed on the part of the reader. Selected parts of Ref. 1 are considered required reading before delving into the details of the programs included in this thesis. Part B of the Procedure and Part 1 of Appendix A are included only as aids and are not in themselves a complete review of programming procedures.

Several philosophies have prevailed throughout the writing of these programs. Foremost, the simplicity of the program routines is such that users may readily understand

the processes being carried out. Since these programs essentially form the bases for more precise programs of this nature, the computations are broken up into relatively short steps to facilitate the alteration of criteria used in the program. The criteria used in these programs are of necessity quite elementary. This restriction was one of the author's, not of the computer. An effort has been made to maintain a factor of safety of 1.0 throughout the program within the bounds of the criteria used. This was done since a uniformly strong structure is considered to be most desirable.

The program for selecting scantlings has been written for optimizing the amidships design within ranges of web frame spacing and numbers of equally spaced longitudinals. The program for computing the dimensions of the transverse web frame follows prescribed rules for designing built up beams. The web thickness is kept constant and other dimensions are varied. Both programs operate on the stress schedule approach of design.

The program for sizing the transverse web frame requires that the number of longitudinals and frame spacing be specified and remain constant throughout the program. This is due to the limitations involved in introducing ship's weights into the problem.

Admittedly there are shortcomings to be found in these programs. These programs are believed to be the first of this type, and it is felt that a considerable amount of improvement is both possible and probably quite desirable.

It is emphasized that the answers, which these programs produce, are not in themselves conclusive. These answers do require a fair amount of evaluation. However, the idea of condensing several days of manual calculations into as many minutes of machine calculations makes this project a very worthwhile endeavor indeed.

II. PROCEDURE

PART A

PREPARATION OF SCANTLING DATA

The data which describes the shape of the scantlings was obtained directly from the AISC Manual (1957) for "T" sections and was computed from the information tabulated in ref. 2 in the case of "I-T" sections. This latter information was calculated by hand but has not been completely verified for accuracy.

The following terminology pertains to the conversion of data for I-T beam-plate sections to that of I-T beam sections:

A_2 area of stiffener-plate combination

A_3 area of stiffener alone

c'_3 distance of neutral axis from the flange of the stiffener alone

d depth of stiffener

I_2 moment of inertia of stiffener-plate combination

I_3 moment of inertia of the stiffener alone

t plate thickness

YF distance of neutral axis from the flange of the stiffener-plate combination

YP distance of neutral axis from the plate of the stiffener-plate combination

λ effective width of plating

Calculations were made from tabulated values for which: $\lambda = 60$, $t = 1"$

$$A_2 = A_3 + \lambda t^2 = A_3 + 60$$

$$YF - c_3' = \frac{\lambda t^2}{A_2}\left(d - c_3' + \frac{t}{2}\right) = \frac{A_2 - A_3}{A_2}\left(YF + YP - c_3' - \frac{t}{2}\right)$$

$$(YF - c_3')\left(1 - \frac{A_2 - A_3}{A_2}\right) = \frac{A_2 - A_3}{A_2}\left(YP - t/2\right)$$

$$(YF - c_3')\left(\frac{A_3}{A_2}\right) = \left(\frac{A_2 - A_3}{A_2}\right)\left(YP - t/2\right)$$

$$(YF - c_3') = \frac{\lambda t}{A_3}\left(YP - \frac{t}{2}\right) = \frac{1}{A_3}(60YP - 30)$$

$$c_3' = YF - \frac{1}{A_3}(60YP - 30)$$

$$I_2 = I_3 + A_3(YF - c_3')^2 + \frac{\lambda t^4}{12} + \lambda t^2\left(YP - \frac{t}{2}\right)^2$$

$$I_3 = I_2 - A_3(YF - c_3')^2 - \frac{\lambda t^4}{12} - \lambda t^2\left(YP - \frac{t}{2}\right)^2$$

$$I_3 = I_2 - A_3(YF - c_3')^2 - 5 - 60YP^2 + 60YP - 15$$

$$I_3 = I_2 - (60YP - 30)^2 - 60YP^2 + (60YP - 30) + 10$$

The values of I_{3YY} for I-T sections were assumed to be approximately one half that of the uncut I sections.

The scantlings are stored in order of increasing cross sectional areas. For each scantling, the following order of data is used: USN designation, A_3(area), c_3' (dist. of neutral axis from flange), I_3 (moment of inertia about neutral axis), I_{3YY}(moment of inertia about axis of symmetry), o, o, d (depth).

PART B

PROGRAMMING NOTES

The following subroutines are employed by the programs in this thesis:

Subroutine	Mnemonic Code	SHARE Designation	SHARE Distribution list	SYN
Square Root	SQRT	MISRT1	399	/356
Sine	SIN	UAS⁄C1	013	/423
Cosine	COS	UAS⁄C1	013	/424
Generalized Print	BLOCK	UABDC1	72	/520
Write on Tape	WOT	UASTH1	72	/1376
Post Mortem	PMR	MICMD1	NON-SHARE	/121

The SYN octal number designations refer to frequently used subroutines currently listed under PAK at the Computation Center at M.I.T. (ref. 7a).

These programs were written in accordance with SHARE Assembly procedures and are available in both mnemonic and absolute binary form at the Department of Naval Architecture and Marine Engineering at M.I.T. Moreover, these programs were written as an Automatic Operator Program (ref. 7b). The administrative instructions at the beginning and end of these programs pertain specifically to the above.

The programs are each broken up into three parts: Data, Program and Input. The parts have been set up through administrative instructions so that the first two parts may be read into the IBM 704 computer in absolute binary form, and the Input information may be read in in the more convenient decimal form to be subsequently assembled with the other two parts. The print out format is under program control.

All lists of information which are tagged to an index register in the program are terminated by a set of -1.0's. Thus, for each list of data or intermediate information, a positive end of the list escape is provided. If an escape occurs in the data listings, i.e., all plate thicknesses or all scantlings did not meet the criteria for a station, indication of such an escape is recorded for subsequent post mortem information. However, most of the loops use this means for their termination during the normal course of computations.

A block of registers starting with LOC are used to store intermediate and final values resulting from the calculations. LOC is the station number for scantling or plate centerline. LOC+1 and LOC+2 are the z and y coordinates respectively for the station. The two stations beyond the last pertinent one are given the coordinates of (-1.0, -1.0). The loops which are repetitive for each or every other station are terminated by transferring on a negative coordinate. Since all other coordinates are positive, this procedure provides an effective means for terminating many repetitive calculations.

Indexing instructions (TXI) are written without a decrement part. The decrements are placed in these instructions at the beginning of the program. By altering only two or three numbers, the whole program can be altered with respect to size to conform to changing criteria. Care should be taken to insure that all instructions within the program with LOC as an address conform to this change.

Negative numbers are used in the decrements. Indexing instructions are specified by a five character alphabetic code: IND$\alpha\beta$. α stands for all such instructions having the same decrement value. β provides the identification for the particular indexing instruction. Examples: INDAA, INDBS, etc.

Non indexing instructions are specified by a five character alphabetic code: INS$\alpha\beta$. $\alpha\beta$ identifies the particular instruction. For the most part, these instructions are in alphabetic sequence starting with INSAA, INSAB, etc. Exceptions to this rule have resulted from the many modifications which these programs have undergone. The designation "*" refers to "this address" with respect to instructions.

These programs operate in the floating trap mode and provision has been made for setting the accumulator to zero and returning to the main program when an underflow ($AC < 10^{-38}$) occurs. Of course, an overflow ($AC > 10^{+38}$) will stop the program. Few escapes have been written for error returns from subroutines. It has been felt desirable to stop the program wherever such an event occurs.

The post mortem dump includes the information listed under LOC. It is here that nearly all of the intermediate information is stored, and searching for errors should commence in this area if the input cards have been found to be correct. Normally there is no need for the post mortem dump and the PMD, PMR and XPM cards are removed.

PART C

Input and Output Formats for Selection of Plating and Scantlings

1. The following conventions apply to the input format:

   a. The order of reading in and assembling input data is to be the same as that listed below. The units to be used are indicated on the input listing.

   b. Since floating point instructions are used, all numbers comprising the input data must have decimal points inserted.

   c. If the SAP deck is to be assembled for the first time, precede the input program with "CST M885-721-PROGRAM" and use "INPUT" as the address of the ORG card. The octal address of INPUT is used when combining the INPUT program with the absolute binary decks of the DATA and PROGRAM parts.

   Input Format with sample problem inserted:

```
REM INPUT INFORMATION FOR PROGRAM M885
SAP M885-721-INPUT
LST OFF
ORG (the octal address of INPUT)
DEC 30.0          (FT)  DEPTH
DEC 35.0          (FT)  BEAM
DEC 17.0          (FT)  BILGE RADIUS
DEC 11.7          (FT)  FULL LOAD DRAFT
DEC 18.7          (FT)  WAVE CREST HEIGHT ABOVE KEEL
DEC 84.0          (IN)  INITIAL FRAME SPACING
DEC 10.0          (IN)  INCREMENT OF FRAME SPACING
```

```
DEC 84.0          (IN)  FINAL FRAME SPACING
DEC 52.0                INITIAL NUMBER OF LONGITUDINALS
DEC 10.0                INCREMENT OF NUMBER OF LONGITUDINALS
DEC 52.0                FINAL NUMBER OF LONGITUDINALS
DEC 0.05                ACCURACY CRITERION FOR MOM. OF INERT.
DEC 12540.0  (FT-TONS)  BENDING MOMENT, SAGGING
DEC 28100.0  (FT-TONS)  BENDING MOMENT, HOGGING
DEC 4.0           (FT)  MINIMUM HYDROSTATIC HEAD
DEC 60000.0       (PSI) ULTIMATE STRENGTH
DEC 33000.0       (PSI) YIELD STRENGTH IN TENSION
DEC 33000.0       (PSI) YIELD STRENGTH IN COMPRESSION
DEC 30000000.0    (PSI) YOUNG'S MODULUS
DEC 2000.0        (PSI) SECONDARY BENDING STRESS AT PLATE
END 0
```

2. Printout Format with answers for sample problem inserted:

   Note: The program has been altered since Appendix C was typed. Intermediate values of locations of neutral axes are printed out concurrently with intermediate values of moments of inertia.

```
RUN M885-721-PROGRAM
REM AMIDSHIP DESIGN PROBLEM
REM THIS REQUIRES THE SELECTION OF PLATING AND SCANTLINGS
REM FOR A DESIGNATED HULL SHAPE UNDER THE INFLUENCE
REM OF PRESCRIBED FORCES AND MOMENTS
BIN M885-721-DATA-DAVIS*00
BIN M885-721-PROGRAM*00
BIN M885-721-INPUT*00
PMD M885-721-PROGRAM
```

CLR

PAK

RIP M885-721-DATA-DAVIS

RIP M885-721-PROGRAM

RIP M885-721-INPUT

BGN M885-721-PROGRAM

The foregoing information are the administrative instructions pertaining to the program. Next, the intermediate values of moments of inertia (in^4) and locations of neutral axes (in) were printed out. In this case nineteen tries were made before all accuracy criteria were met.

Several comments are in order concerning the print out format. Floating point notation is used in some instances. Two examples are the best illustration of floating point numbers: 0.503E02 = 50.3, 0.607E-01 = 0.0607. The number following the letter E is the power of 10 by which the number preceding the letter E is to be multiplied. Area is given in square inches. A is the web frame spacing in inches, and N is the total number of equally spaced longitudinals. Moments of Inertia are given in units $in.^2 ft.^2$ Inertia pl refers to the moment of inertia for the ship in the sagging condition and similarly inertia min. for the hogging condition. Locations are numbered consecutively as shown in Figure 3 in Appendix C. Z and y distances are measured in inches from the keel along the centerline and base line respectively. Scantlings are indicated by their USN designation with the exception that "I" refers to "I-T" sections. Plate thicknesses are indicated in lbs/square foot.

INERTIA PL= 0.35123213E 05 INERTIA MIN= 0.41415150E 05
NEUTRAL AXIS SAG= 159.3 NEUTRAL AXIS HOG= 199.1

AREA= 0.27954086E 03 N= 62.0 A= 84.0

INERTIA PL= 0.3543546E 05 INERTIA MIN= 0.40221344E 05

LOCATION= 0.0 Z= 0.0 Y= 0.0

10.0X4.00X 11.51
LENGTH/RADIUS OF GYRATION= 30.0

LOCATION= 1.0 Z= 0.1 Y= 13.0 WT= 20.4

LOCATION= 2.0 Z= 1.0 Y= 26.6

10.0X4.000X 11.51
LENGTH/RADIUS OF GYRATION= 30.0

LOCATION= 3.0 Z= 2.8 Y= 40.0 WT= 17.8

LOCATION= 4.0 Z= 5.5 Y= 52.8

10.0X2.750X 9.001
LENGTH/RADIUS OF GYRATION= 30.0

LOCATION= 5.0 Z= 8.9 Y= 66.0 WT= 17.8

LOCATION= 6.0 Z= 13.2 Y= 78.3

10.0X2.750X 9.001
LENGTH/RADIUS OF GYRATION= 30.0

LOCATION= 7.0 Z= 18.4 Y= 91.0 WT= 17.8

LOCATION= 8.0 Z= 24.3 Y= 102.5

10.0X2.750X 9.001
LENGTH/RADIUS OF GYRATION= 29.9

LOCATION= 9.0 Z= 31.0 Y= 114.0 WT= 15.3

LOCATION= 10.0 Z= 38.4 Y= 125.1

10.0X2.750X 9.001
LENGTH/RADIUS OF GYRATION= 29.9

LOCATION= 11.0 Z= 46.5 Y= 136.0 WT= 15.3

LOCATION= 12.0 Z= 55.3 Y= 145.6

10.0X2.750X 9.001
LENGTH/RADIUS OF GYRATION= 29.8

LOCATION= 13.0 Z= 64.7 Y= 155.0 WT= 14.0

LOCATION= 14.0 Z= 74.7 Y= 163.8

10.0X2.750X 9.001
LENGTH/RADIUS OF GYRATION= 29.8

LOCATION= 15.0 Z= 85.3 Y= 172.0 WT= 12.7

LOCATION= 16.0 Z= 96.4 Y= 179.3

10.0X2.750X 9.001
LENGTH/RADIUS OF GYRATION= 29.7

LOCATION= 17.0 Z= 107.9 Y= 186.0 WT= 11.5

LOCATION= 18.0 Z= 119.8 Y= 191.8

10.0X2.750X 9.001
LENGTH/RADIUS OF GYRATION= 29.7

LOCATION= 19.0 Z= 132.1 Y= 197.0 WT= 10.2

LOCATION= 20.0 Z= 144.7 Y= 201.2

8.0X2.250X 6.501
LENGTH/RADIUS OF GYRATION= 29.6

LOCATION= 21.0 Z= 157.6 Y= 205.0 WT= 7.6

LOCATION= 22.0 Z= 170.7 Y= 207.3

8.0X2.250X 6.501
LENGTH/RADIUS OF GYRATION= 29.5

LOCATION= 23.0 Z= 183.9 Y= 209.0 WT= 6.4

LOCATION= 24.0 Z= 197.1 Y= 209.9

8.0X2.250X 6.501
LENGTH/RADIUS OF GYRATION= 29.5

LOCATION= 25.0 Z= 210.5 Y= 210.0 WT= 6.4

LOCATION= 26.0 Z= 223.8 Y= 210.0

8.0X2.250X 6.501
LENGTH/RADIUS OF GYRATION= 29.4

LOCATION= 27.0 Z= 237.1 Y= 210.0 WT= 7.6

LOCATION= 28.0 Z= 250.4 Y= 210.0

8.0X2.250X 6.501
LENGTH/RADIUS OF GYRATION= 29.3

LOCATION= 29.0 Z= 263.7 Y= 210.0 WT= 8.9

LOCATION= 30.0 Z= 277.0 Y= 210.0

8.0X2.250X 6.501
LENGTH/RADIUS OF GYRATION= 29.2

LOCATION= 31.0 Z= 290.4 Y= 210.0 WT= 10.2

LOCATION= 32.0 Z= 303.7 Y= 210.0

10.0X2.750X 9.001
LENGTH/RADIUS OF GYRATION= 29.2

LOCATION= 33.0 Z= 317.0 Y= 210.0 WT= 11.5

LOCATION= 34.0 Z= 330.3 Y= 210.0

10.0X2.750X 9.001
LENGTH/RADIUS OF GYRATION= 29.1

LOCATION= 35.0 Z= 343.6 Y= 210.0 WT= 12.7

LOCATION= 36.0 Z= 356.9 Y= 210.0

10.0X2.750X 9.001
LENGTH/RADIUS OF GYRATION= 29.0

LOCATION= 37.0 Z= 360.0 Y= 200.0 WT= 12.7

LOCATION= 38.0 Z= 360.0 Y= 186.4

10.0X2.750X 9.001
LENGTH/RADIUS OF GYRATION= 29.0

LOCATION= 39.0 Z= 360.0 Y= 173.0 WT= 12.7

LOCATION= 40.0 Z= 360.0 Y= 159.8

10.0X2.750X 9.001
LENGTH/RADIUS OF GYRATION= 29.0

LOCATION= 41.0 Z= 360.0 Y= 146.0 WT= 12.7

LOCATION= 42.0 Z= 360.0 Y= 133.2

10.0X2.750X 9.001
LENGTH/RADIUS OF GYRATION= 29.0

LOCATION= 43.0 Z= 360.0 Y= 120.0 WT= 12.7

LOCATION= 44.0 Z= 360.0 Y= 106.5

10.0X2.750X 9.001
LENGTH/RADIUS OF GYRATION= 29.0

LOCATION= 45.0 Z= 360.0 Y= 93.0 WT= 12.7

LOCATION= 46.0 Z= 360.0 Y= 79.9

10.0X2.750X 9.001
LENGTH/RADIUS OF GYRATION= 29.0

LOCATION= 47.0 Z= 360.0 Y= 67.0 WT= 12.7

LOCATION= 48.0 Z= 360.0 Y= 53.3

10.0X2.750X 9.001
LENGTH/RADIUS OF GYRATION= 29.0

LOCATION= 49.0 Z= 360.0 Y= 40.0 WT= 12.7

LOCATION= 50.0 Z= 360.0 Y= 26.6

10.0X2.750X 9.001
LENGTH/RADIUS OF GYRATION= 29.0

LOCATION= 51.0 Z= 360.0 Y= 13.0 WT= 12.7

LOCATION= 52.0 Z= 360.0 Y= 0.0

10.0X2.750X 9.001
LENGTH/RADIUS OF GYRATION= 29.0

LOCATION= 53.0 Z= -1.0 Y= -1.0

TER M885-721-PROGRAM

PART D

Input and Output Formats for Sizing the Transverse Web Frame

1. The Input Format is the same as that for Part C just preceding with the following exceptions:

a. Initial and final values for each of the following must be equal: number of longitudinals and frame spacing. Note: some value greater than zero must be inserted for increments of numbers of longitudinal and increments of frame spacing.

b. Insert the following information immediately before "END 0" in the INPUT program described in Part C:

```
ORG (octal address of LOAD)
DEC 700., 500., 200., 200., 0., 0., 0., 0., 0.
DEC 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0.
DEC 100., 100., 100., 100., 100., 100., 100., 100.,
DEC 100., 100.
```

The LOAD data pertains to the weights (in lbs.) applied at the intersections of scantlings and the web frame by machinery, etc., within the ship. The first value under LOAD refers to the weight applied at the keel. Successive values refer to weights applied at successive even numbered stations. It is for this reason that the number of equally spaced longitudinals must be specified and remain fixed. The preceding format permits stacking of data on relatively few cards. Note that decimal points must be inserted.

The same convention applies to the ORG cards used in part C as well as that of the preceding format. In the latter case "LOAD" is the title of the ORG card when "INPUT" is so used in the preceding case. The CST instruction of part C covers both LOAD and INPUT data in this case.

The output format indicates the dimensions of the web frame. All dimensions are in inches.

Intermediate values of the redundant force and moment are printed out. These values are indicated in the Results and Discussion. The format which follows is given in addition to the printout format of the previous subsection.

LOCATION= 0.0 Z= 0.0 Y= 0.0

TW= . TF= . D= . W= .

LOCATION= 2.0 Z= 1.0 Y= 26.6

TW= . TF= . D= . W= .

LOCATION= 4.0 Z= 5.5 Y= 52.8

TW= . TF= . D= . W= .

LOCATION= 6.0 Z= 13.2 Y= 78.3

TW= . TF= . D= . W= .

LOCATION= 8.0 Z= 24.3 Y= 102.5

TW= . TF= . D= . W= .

LOCATION= 10.0 Z= 38.4 Y= 125.1

TW= . TF= . D= . W= .

LOCATION= 12.0 Z= 55.3 Y= 145.6

TW= . TF= . D= . W= .

LOCATION= 14.0 Z= 74.7 Y= 163.8

TW= . TF= . D= . W= .

LOCATION= 16.0 Z= 96.4 Y= 179.3.

TW= . TF= . D= . W= .

LOCATION= 18.0 Z= 119.8 Y= 191.8

TW= . TF= . D= . W= .

LOCATION= 20.0 Z= 144.7 Y= 201.2

TW= . TF= . D= . W= .

LOCATION= 22.0 Z= 170.7 Y= 207.3

TW= . TF= . D= . W= .

LOCATION= 24.0 Z= 197.1 Y= 209.9

TW= . TF= . D= . W= .

LOCATION= 26.0 Z= 223.8 Y= 210.0

TW= . TF= . D= . W= .

LOCATION= 28.0 Z= 250.4 Y= 210.0

TW= . TF= . D= . W= .

LOCATION= 30.0 Z= 277.0 Y= 210.0

TW= . TF= . D= . W= .

LOCATION= 32.0 Z= 303.7 Y= 210.0

TW= . TF= . D= . W= .

LOCATION= 34.0 Z= 330.3 Y= 210.0

TW= . TF= . D= . W= .

LOCATION= 36.0 Z= 356.9 Y= 210.0

TW= . TF= . D= . W= .

LOCATION= 38.0 Z= 360.0 Y= 186.4

TW= . TF= . D= . W= .

LOCATION= 40.0 Z= 360.0 Y= 159.8

TW= . TF= . D= . W= .

LOCATION= 42.0 Z= 360.0 Y= 133.2

TW= . TF= . D= . W= .

LOCATION= 44.0 Z= 360.0 Y= 106.5

TW= . TF= . D= . W= .

LOCATION= 46.0 Z= 360.0 Y= 79.9

TW= . TF= . D= . W= .

LOCATION= 48.0 Z= 360.0 Y= 53.3

TW= . TF= . D= . W= .

LOCATION= 50.0 Z= 360.0 Y= 26.6

TW= . TF= . D= . W= .

LOCATION= 52.0 Z= 360.0 Y= 0.0

TW= . TF= . D= . W= .

III. RESULTS

The numerical results obtained from the computer solutions of the first program are contained in subsection C-2 under Procedure.

The first program has been run and is known to be correct. This program selects longitudinals and plating for a ship's hull. This program has been completely verified by hand calculations. The input and output formats are designed for convenience and are contained in section C of the Procedure.

The second program, that of sizing the transverse web frame, has been written but it is not working. The part of this program up through page 129 is known to be correct. The part of this program written on pages 130 through 138 are believed to be correct, but bear checking. It is felt that the difficulty lies somewhere in pages 139 through 152.

Both programs have the following limitations:

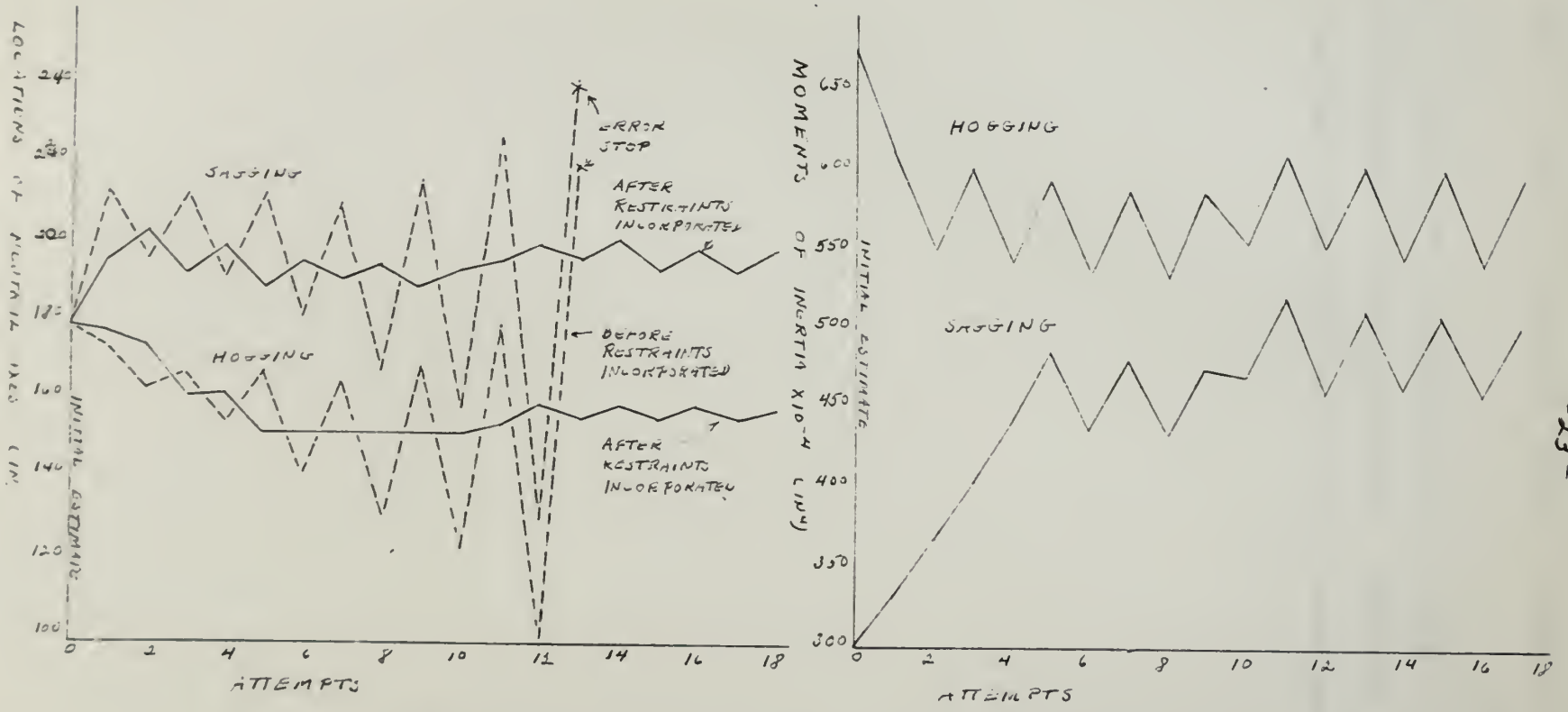
1. The frame scantlings are evenly spaced and are placed symmetrically about the ship centerline.
2. The points defining the hull section are symmetrical about the ship centerline.
3. One of these points is on the centerline keel.
4. The hull shape is defined by its beam, depth, and bilge radius.

The web frame program has the following additional limitations (aside from the fact that it is not working):

1. Symmetrical loading with respect to the centerline.
2. No stanchions are used.

3. No account is taken of shear strains or shear stresses.

Computer time for calculation of scantlings and plating was around 5 minutes. Computer time for calculation of the web frame dimensions might be as much as 20 minutes.



PLOT OF INTERMEDIATE VALUES OF LOCATIONS OF NEUTRAL AXES AND OF MOMENTS OF INERTIA

IV. DISCUSSION OF RESULTS

The aims of this thesis as originally specified were not fully met. As originally planned, the program for selecting scantlings and plating was to have been used to generate curves indicating optimum numbers of longitudinals and frame spacings for different hull geometries under bending and hydrostatic loads. This aim was not met due to a critical shortage of computer time available. Moreover, most of the available computer time was utilized in the debugging phases. However, this program was written to select the optimum (least weight) combination of number of longitudinals and frame spacing and to print out the data for this combination.

One of the more important points to note is the fact that these programs are written for a factor of safety of 1.0 on the specified yield stress. In both programs, stress schedules provide the fundamental criterion for selecting components of the hull structure. In all cases stresses are assumed to be uniaxial. The sum of stresses resulting from different loadings are never permitted to exceed the specified yield stresses.

The graphs on the opposite page are included to point out the area which deserves immediate attention for the sake of improving these programs. The use of four related values z_c^+, z_c^-, I_l^+ and I_l^- makes this program inherently unstable. Accordingly, moments of inertia are varied by a percentage amount (10%) until computed and assumed values

agree to within a specified amount. In this case the accuracy criterion was five percent. As is indicated in these graphs, the use of computed values of locations of neutral axes as the new assumed values led to an unstable solution. This difficulty was rectified by using the mean of assumed and computed values of locations of neutral axes as the new assumed values.

The process of making new estimates of moments of inertia is still considered to be unsatisfactory since too many attempts must be made to arrive at a solution.

The transverse web frame program did not run to a solution. This program was run for 10 minutes during which time two values each of redundant moment and redundant force were obtained. It appears as though the difficulty might be associated with the flow diagram for this program rather than to any specific instruction. There was insufficient computer and calendar time available to pursue this matter further.

Perhaps one of the more important parts of this investigation is the use of a logical approach to the amidship's hull design. The computer is a relatively stupid beast and has no capability other than to obey instructions at an incredibly fast rate. Neither esthetic values nor the successes of previous designs can be used unless they are somehow incorporated into the specific criteria within the program.

The criteria used in these programs are usually quite simple. The main purpose here is to at least provide a

(Note: there is no Page 25)

logical position in the programs for more exact criteria. In a sense, these programs are frameworks for future developments of this nature. It is emphasized that the simplicity of the criteria used was not caused by the computer but rather by the calendar time available to the author.

It is felt that with a suitably sized shoe horn these programs can be written for the IBM-650 computer. This computer has 4000 memory addresses as compared with the 32786 core locations plus magnetic drums and tapes available for the IBM-704 computers. This comparison should provide an indication of how much these programs can be expanded if the IBM-704 computer or its successors are to be used.

A considerable portion of time spent on this project was devoted to debugging the programs. An appreciation of this fact can be gained by noting that every letter, number, comma and period must be correct. The programs were written in such a manner as to make debugging a relatively easy process. Nevertheless, this was the most frustrating and discouraging part of this investigation.

These programs are as well documented as could be done within a reasonable number of pages. Again it should be pointed out that some of the criteria bears checking and refining. It is hoped that users will find this thesis as valuable to them in their work as it has been to the author in preparing it.

V. CONCLUSIONS AND RECOMMENDATIONS

1. Conclusions:

The results of experiments regarding structural components can be readily incorporated into programs such as those contained in this thesis. The results must be in some mathematical form but can be as complex as is desired to reflect actual observed conditions.

Digital computers can be used to solve extremely complex structural problems. Ref. 8 contains an example of such a structural problem. Here, a grillage framework for a destroyer type hull is analyzed. This analysis is nearly impossible to carry out by hand within a reasonable amount of time. It is felt that an era of extensive hand calculations for the analysis and design of complex structures is rapidly coming to an end. The high degree of engineering required for efficient structures, of the complexity of a ship's hull for instance, require the use of high speed computers for design and analysis processes.

In general, the limitations imposed by the computer on a problem are less restrictive than those imposed by manual methods. Two observations bear this fact out. First, the computer can be used to solve complex differential equations which may arise from proven theory almost as efficiently as it can the normal algebraic expressions often encountered in design work. Secondly, computer programs can be expanded to encompass a wide range of engineering knowledge to be applied in the design processes accomplished by the particular programs.

Accordingly, much more efficient use can be made of the most precise theories available. It would be remiss not to point out the fact that the designer's time can be much more effectively used to evaluate the results of designs calculated by the computer rather than doing the calculations manually.

2. Recommendations:

The programs in this thesis should be expanded to include the best engineering knowledge and theory available. As has been pointed out in the discussion of results, the criteria used in these programs are quite basic. There is a considerable amount of room for improvement in this field.

Once the above has been carried out to a reasonable extent, investigations should be made to adapt this approach to designing a grillage network similar to that of Ref. 8. Once this has been done, it is felt that the programs will be quite valuable indeed in designing hull structures for the destroyer type ships. In addition, these programs could be adapted to other types of hulls and an effort should be made in that direction.

VI. APPENDICES

APPENDIX A

GLOSSARY

1. List of Frequently Used Computer Instructions

Explanations accompanying the following operation codes are not necessarily technically correct. However, they are deemed sufficient for readers who have had little or no experience in programming for the IBM-704 Data Processing System.

CLA Y	Clear the accumulator (AC), (Set to 0) and add the contents of address Y.
FAD Y	Add (floating point) the contents of Y to the contents of the accumulator.
STO Y	Store the contents of the (AC) in the address Y.
LDQ Y	Load the multiplier quotient register (MQ) with the contents of Y.
STQ Y	Store the contents of the (MQ) in the address Y.
LDQ X FMP Y STO Z	A series of instructions in which the contents of X are multiplied by the contents of Y and the result thereof is stored in the address Z.
CLA X FDP Y STQ Z	A series of instructions in which the contents of X are divided by the contents of Y and the quotient thereof is stored in the address Z.
CAS Y	Compare the contents of the (AC) with those of the address Y: If the c(AC) > c(Y), go to the next instruction. If the c(AC) = c(Y), skip one instruction. If the c(AC) < c(Y), skip two instructions.
NOP	No operation, go to the next instruction.
HTR	Error stop
HLT	End of program
REM	Remark, this operation code has no significance other than that of information.
CHS	Change the algebraic sign of the contents of (AC).
SSP	Set the algebraic sign of the contents of (AC) plus.
SSM	Set the algebraic sign of the contents of (AC) minus.
TRA Y	Absolute transfer of control to the instruction having the address Y.

TMI Y — Transfer to Y if the contents of the (AC) are negative.

TLQ Y — Transfer to Y if the contents of the (AC) are greater than the contents of the (MQ).

TSX ---,4 — Exit for a subroutine.

LXD NIX,K — Used to set the contents of index register(s) K to zero.

TXI Y,K,N — Transfer control to Y and increment the contents of index register(s) K by the amount N. In this and the previous instruction the value of K affects the following registers:

K : 1, 2, 3, 4, 5, 6, 7.

Index Registers: 1, 2,1&2, 4,2&3,2&4,1&2&4.

The TXI instruction changes the effective addresses of all instructions tagged to index register K. In these programs, negative numbers are used for N. For example:

LOC,1 = LOC when index register 1 = 0
LOC,2 = LOC+50 " " " 2 = -50
LOC+5,1 = LOC+75 " " " 1 = -70

2. Index of Notation:

The following symbols and definitions are those commonly used in this thesis. Inconsistencies in their usage are explained where they occur.

A	Area
A_1^+	Total effective area of ship's hull in the sagging condition.
A_1^-	Total effective area of ship's hull in the hogging condition.
A_2	Total area of a beam-plate combination.
A_2^-	Effective area of a beam-plate combination in compression.
a	Frame spacing.
a_o	Initial frame spacing.
Δa	Increment of frame spacing.
a_f	Final frame spacing.
B	Beam.
b	Longitudinal spacing.
b_o	Initial longitudinal spacing.
c	Location of neutral axis of beam or beam-plate combination.
c_2	Distance of neutral axis from extreme plate fibre of total area of beam-plate combination.
c_2^-	Distance of neutral axis from extreme plate fibre of effective area of beam-plate combination in compression.
c_2'	Distance of neutral axis from extreme flange fibre of total area of beam-plate combination.
$c_2'^-$	Distance of neutral axis from extreme flange fibre of effective area of beam-plate combination in compression.
c_3'	Distance of neutral axis from extreme flange fibre of total area of beam alone.
$c\text{-}w$	Vertical load on transverse web frame.
D	Depth of ship's hull, width of web plating.
d	Depth of beam.
E	Young's Modulus.
F	Full load draft.
H	Head of salt water.
H_o	Minimum head of salt water.

H_w Head of salt water due to ship in the hogging condition.
H_θ Head of salt water due to ship inclined to a specified angle of heel.

I Moment of inertia.
I_1^+ Effective moment of inertia of the ship hull in the sagging condition.
I_1^- Effective moment of inertia of the ship hull in the hogging condition.
ΔI Specified accuracy criterion for moment of inertia and redundant forces and moments.
I_2 Effective moment of inertia of the beam-plate combination under lateral load.
I_2^- Effective moment of inertia of the beam-plate combination under end compressive load.
I_{2YY} Total moment of inertia of the beam-plate combination about the y-y axis. (axis of symmetry)
I_{2YY}^- Effective moment of inertia of the beam-plate combination about the y-y axis under end compression load.
I_3 Moment of inertia of the beam alone about its x-x axis.
I_{3YY} Moment of inertia of the beam alone about its axis of symmetry.

k Radius of gyration.

M Bending moment.

M_o Redundant bending moment.
M_{ex} Moment due to external loads.
M_1^+ Ship (primary) bending moment in the sagging condition.
M_1^- Ship (primary) bending moment in the hogging condition.
M_2 Secondary bending moment due to lateral load on the beam-plate combination.

n Number of longitudinals.

n_o Initial number of longitudinals.
Δn Increment of number of longitudinals.
n_f Final number of longitudinals.

P Axial force.
P_o Redundant axial force
P_{ex} Axial force due to external loads.

Q First moment of area, shear force.

R Bilge radius.

S Shear force.

t Plate thickness.

t_f Flange thickness.
t_w Web thickness.

V Total vertical shear force.

W Wave crest height above keel, ship in hogging condition.

y Coordinate direction perpendicular to centerline plane of ship's hull.

z Coordinate direction in the centerline plane and perpendicular to the base line in the fore and aft direction.

z_c^+ Distance from the base line to the neutral axis of the hull in the sagging condition.

z_c^- Distance from the base line to the neutral axis of the hull in the hogging condition.

σ Stress intensity.

σ_A Axial stress.

σ_{UT} Ultimate strength.

σ_{YP}^+ Yield strength in tension.

σ_{YP}^- Yield strength in compression.

σ_1^+ Primary stress (tension) due to bending of ship hull.

σ_1^- Primary stress (compression) due to bending of ship hull.

σ_2 Secondary stress due to lateral load on beam-plate combination.

σ_3 Tertiary stress due to lateral load on plating.

λ Effective breadth of plating under lateral load.

λ^- Effective width of plating under end compression.

θ Angle.

$\Delta\theta$ Increment of angle.

APPENDIX B

PLATE AND SCANTLING DATA

```
RUN M885-721-PROGRAM
REM AMIDSHIP DESIGN PROBLEM
REM THIS REQUIRES THE SELECTION OF PLATING AND SCANTLINGS
REM FOR A DESIGNATED HULL SHAPE UNDER THE INFLUENCE
REM OF PRESCRIBED FORCES AND MOMENTS.
SAP M885-721-DATA-DAVIS
LST NONE
PRG OFF
ORG /70000
```

```
      REM PLATE DATA, IN ORDER OF INCREASING THICKNESSES,
      REM WT PER SQUARE FOOT, THICKNESS, IN INCHES, THICKNESS
      REM SQUARED IN THAT ORDER
PLATE DEC 5.10,0.125,0.015625,6.37,0.1562,0.024414,7.65,0.1875,0.035156
      DEC 8.92,0.2187,0.047830,10.20,0.2500,0.0625,11.47,0.2812
      DEC 0.079073,12.75,0.3125,0.097656,14.02,0.3437,0.118130,15.30
      DEC 0.3750,0.140625,17.85,0.4375,0.191406,20.40,0.5000,0.250000
      DEC 22.95,0.5625,0.316406,25.50,0.6250,0.390625,28.05,0.6875
      DEC 0.472656,30.60,0.7500,0.562500,35.70,0.8750,0.765625,40.80
      DEC 1.0000,1.000000,45.90,1.1250,1.265625,51.00,1.2500,1.562500
      DEC 61.20,1.5000,2.250000
      DEC -1.0,-1.0,-1.0
      REM SCANTLING DATA, U S N BEAM DESIGNATION, I
      REM REFERS TO I-T SECTIONS, DEC DATA, AREA, DIST OF
      REM NEUTRAL AXIS TO FLANGE, TWO MOMENTS OF INERTIA,
      REM TWO BLANKS, DEPTH, IN THAT ORDER
SCANT BCD 3  3.0X1.875X 2.20T
      DEC 0.65,0.84,0.58,0.082,0.,0.,3.00
      BCD 3  4.0X2.250X 3.25T
      DEC 0.96,1.18,1.59,0.17,0.,0.,4.00
      BCD 3  6.0X1.875X 4.40I
      DEC 0.99,2.19,4.71,0.09,0.,0.,6.00
      BCD 3  3.0X4.000X 4.25T
      DEC 1.25,0.64,0.90,0.94,0.,0.,2.92
      BCD 3  7.0X2.125X 5.50I
      DEC 1.25,2.60,7.70,0.13,0.,0.,7.00
      BCD 3  5.0X2.750X 4.50T
      DEC 1.32,1.53,3.46,0.30,0.,0.,5.00
      BCD 3  4.0X4.000X 5.00T
      DEC 1.48,0.96,2.15,1.00,0.,0.,3.95
      BCD 3  8.0X2.250X 6.50I
      DEC 1.53,2.87,9.00,0.17,0.,0.,8.00
      BCD 3  5.0X4.000X 5.75T
      DEC 1.69,1.35,4.15,1.00,0.,0.,4.94
      BCD 3  6.0X3.000X 5.90T
      DEC 1.72,1.88,6.59,0.49,0.,0.,6.00
      BCD 3  3.0X4.000X 6.00T
      DEC 1.77,0.67,1.30,1.44,0.,0.,3.00
      BCD 3  6.0X4.000X 8.50I
      DEC 1.77,1.78,7.12,0.95,0.,0.,5.83
      BCD 3  4.0X4.000X 6.50T
      DEC 1.91,1.03,2.90,1.31,0.,0.,4.00
      BCD 3  6.0X4.000X 7.00T
      DEC 2.07,1.76,7.70,1.13,0.,0.,5.96
      BCD 3 10.0X2.750X 9.00I
      DEC 2.17,3.91,24.48,0.31,0.,0.,10.00
      BCD 3  8.0X4.000X10.00I
      DEC 2.19,2.72,18.19,1.00,0.,0.,7.90
      BCD 3  5.0X4.000X 7.50T
      DEC 2.20,1.37,5.46,1.39,0.,0.,5.00
      BCD 3  4.0X4.000X 7.50T
      DEC 2.22,1.00,3.29,1.65,0.,0.,4.06
      BCD 3  3.0X4.000X 8.00T
      DEC 2.36,0.67,1.66,2.16,0.,0.,3.13
      BCD 3  6.0X4.000X 8.25T
      DEC 2.43,1.76,9.02,1.39,0.,0.,6.00
```

```
BCD 3  5.0X4.000X 8.50T
DEC 2.49,1.32,6.07,1.73,0.,0.,5.06
BCD 3  6.0X4.000X12.00T
DEC 2.49,1.97,13.49,1.45,0.,0.,6.00
BCD 3  4.0X4.000X 8.50T
DEC 2.50,0.84,3.21,3.36,0.,0.,4.00
BCD 3 10.0X4.000X 11.5I
DEC 2.63,3.45,26.12,1.01,0.,0.,9.87
BCD 3 12.0X3.000X 11.8I
DEC 2.75,4.52,42.53,0.49,0.,0.,12.00
BCD 3  5.0X4.000X  9.5T
DEC 2.80,1.28,6.70,2.09,0.,0.,5.13
BCD 3  6.0X4.000X  9.5T
DEC 2.81,1.67,10.2,1.84,0.,0.,6.08
BCD 3  8.0X4.000X 13.0I
DEC 2.88,2.82,23.62,1.31,0.,0.,8.00
BCD 3  4.0X5.250X 10.0T
DEC 2.94,0.83,3.66,4.25,0.,0.,4.07
BCD 3  5.0X5.750X 10.5T
DEC 3.10,1.06,6.31,4.87,0.,0.,4.95
BCD 3  6.0X4.000X 11.0T
DEC 3.24,1.63,11.7,2.27,0.,0.,6.16
BCD 3  6.0X4.000X 16.0I
DEC 3.26,1.89,16.02,2.16,0.,0.,6.25
BCD 3  8.0X4.000X 15.0I
DEC 3.27,2.62,22.00,1.65,0.,0.,8.12
BCD 3 12.0X4.000X 14.0I
DEC 3.30,4.54,56.83,1.13,0.,0.,11.91
BCD 3 10.0X4.000X 15.0I
DEC 3.40,3.60,39.55,1.40,0.,0.,10.00
BCD 3  8.0X5.250X 17.0I
DEC 3.48,2.30,23.27,3.4,0.,0.,8.00
BCD 3  5.0X5.750X 12.5T
DEC 3.67,1.02,7.12,6.34,0.,0.,5.04
BCD 3 10.0X4.000X 17.0I
DEC 3.77,3.52,45.07,1.73,0.,0.,10.12
BCD 3 12.0X4.000X 16.5I
DEC 3.86,4.56,66.59,1.40,0.,0.,12.00
BCD 3  6.0X6.500X 13.5T
DEC 3.98,1.21,11.4,8.30,0.,0.,5.98
BCD 3  8.0X5.250X 20.0I
DEC 4.03,2.28,28.14,4.30,0.,0.,8.14
BCD 3 10.0X4.000X 19.0I
DEC 4.18,3.37,45.92,2.10,0.,0.,10.25
BCD 3  5.0X5.750X 14.5T
DEC 4.27,1.05,8.38,7.61,0.,0.,5.11
BCD 3 12.0X4.000X 19.0I
DEC 4.34,4.36,70.84,1.85,0.,0.,12.16
BCD 3 10.0X5.750X 21.0I
DEC 4.35,2.86,42.33,4.90,0.,0.,9.90
BCD 3  7.0X6.750X 15.0T
DEC 4.41,1.59,19.0,8.77,0.,0.,6.93
BCD 3  6.0X6.500X 15.5T
DEC 4.56,1.22,13.0,9.90,0.,0.,6.04
BCD 3  8.0X6.500X 24.0I
DEC 4.63,2.00,30.86,9.10,0.,0.,7.93
```

```
BCD 3 12.0X4.000X 22.0I
DEC 4.94,4.26,81.09,2.28,0.,0.,12.31
BCD 3  7.0X6.750X 17.0T
DEC 5.00,1.55,21.1,10.6,0.,0.,7.00
BCD 3 10.0X5.750X 25.0I
DEC 5.06,2.87,56.75,6.4,0.,0.,10.08
BCD 3  6.0X6.500X 18.0T
DEC 5.29,1.26,15.3,11.9,0.,0.,6.12
BCD 3  8.0X7.000X 18.0T
DEC 5.40,1.90,30.7,11.1,0.,0.,7.93
BCD 3  8.0X6.500X 28.0I
DEC 5.42,2.04,34.90,10.8,0.,0.,8.06
BCD 3 12.0X6.500X 27.0I
DEC 5.53,3.44,84.58,8.3,0.,0.,11.95
BCD 3  7.0X6.750X 19.0T
DEC 5.59,1.56,23.50,12.3,0.,0.,7.06
BCD 3  8.0X7.000X 20.0T
DEC 5.88,1.82,33.20,13.3,0.,0.,8.00
BCD 3 10.0X5.750X 29.0I
DEC 5.88,2.88,63.17,7.6,0.,0.,10.22
BCD 3 12.0X6.500X 31.0I
DEC 6.30,3.43,99.63,9.9,0.,0.,12.09
BCD 3 14.0X6.750X 30.0I
DEC 6.38,4.37,137.99,8.8,0.,0.,13.86
BCD 3 10.0X8.000X 33.0I
DEC 6.45,2.51,63.90,18.3,0.,0.,9.75
BCD 3  8.0X7.000X 22.5T
DEC 6.62,1.87,37.8,15.2,0.,0.,8.06
BCD 3 14.0X6.750X 34.0I
DEC 7.15,4.26,151.08,10.7,0.,0.,14.00
BCD 3 12.0X6.500X 36.0I
DEC 7.34,3.57,125.17,11.9,0.,0.,12.24
BCD 3  8.0X7.000X 25.0T
DEC 7.35,1.89,42.2,17.4,0.,0.,8.13
BCD 3  9.0X7.500X 25.0T
DEC 7.35,2.14,53.9,18.6,0.,0.,9.00
BCD 3 10.0X8.000X 39.0I
DEC 7.54,2.47,72.29,22.5,0.,0.,9.94
BCD 3 16.0X7.000X 36.0I
DEC 7.78,5.10,213.49,11.1,0.,0.,15.85
BCD 3 12.0X8.000X 40.0I
DEC 7.91,3.17,121.08,22.1,0.,0.,11.94
BCD 3 14.0X6.750X 38.0I
DEC 7.96,4.29,172.97,12.3,0.,0.,14.12
BCD 3  9.0X7.500X 27.5T
DEC 8.09,2.16,59.6,21.0,0.,0.,9.06
BCD 3 16.0X7.000X 40.0I
DEC 8.50,5.06,250.63,13.3,0.,0.,16.00
BCD 3  8.0X8.500X 29.0T
DEC 8.52,1.70,49.6,30.2,0.,0.,7.93
BCD 3 10.0X8.000X 45.0I
DEC 8.66,2.53,88.43,26.6,0.,0.,10.12
BCD 3 14.0X8.000X 43.0I
DEC 8.70,3.84,178.37,22.6,0.,0.,13.68
BCD 3  9.0X7.500X 30.0T
DEC 8.82,2.17,64.8,23.5,0.,0.,9.12
```

```
BCD 3 12.0X8.000X 45.0I
DEC 8.94,3.31,146.87,25.0,0.,0.,12.06
BCD 3 10.5X8.250X 31.0T
DEC 9.12,2.59,93.7,26.6,0.,0.,10.49
BCD 3  8.0X8.500X 32.0T
DEC 9.40,1.73,48.3,34.2,0.,0.,8.00
BCD 3  9.0X8.750X 32.0T
DEC 9.40,1.93,61.8,35.2,0.,0.,8.94
BCD 3 16.0X7.000X 45.0I
DEC 9.59,5.08,274.69,15.3,0.,0.,16.12
BCD 3 14.0X8.000X 48.0I
DEC 9.70,3.88,202.08,25.7,0.,0.,13.81
BCD 3 12.0X8.000X 50.0I
DEC 9.94,3.32,159.32,23.2,0.,0.,12.19
BCD 3 10.5X8.250X 34.0T
DEC 10.01,2.59,102.8,30.2,0.,0.,10.57
BCD 3 12.0X10.00X 53.0I
DEC 10.16,2.96,151.29,48.1,0.,0.,12.06
BCD 3  9.0X8.750X 35.0T
DEC 10.28,1.96,68.1,39.2,0.,0.,9.00
BCD 3  8.0X8.500X 35.5T
DEC 10.43,1.77,54.0,38.9,0.,0.,8.08
BCD 3 16.0X7.000X 50.0I
DEC 10.65,5.13,310.26,17.4,0.,0.,16.25
BCD 3 14.0X8.000X 53.0I
DEC 10.72,3.95,229.16,28.8,0.,0.,13.94
BCD 3 10.5X8.250X 36.5T
DEC 10.73,2.60,110.2,33.1,0.,0.,10.62
BCD 3 18.0X7.500X 50.0I
DEC 10.76,5.81,392.61,18.6,0.,0.,18.00
BCD 3 12.0X10.00X 58.0I
DEC 11.05,2.97,170.50,53.7,0.,0.,12.19
BCD 3 12.0X9.000X 38.0T
DEC 11.18,3.00,151.1,38.3,0.,0.,11.95
BCD 3  9.0X8.750X 38.5T
DEC 11.32,1.99,75.3,44.3,0.,0.,9.08
BCD 3  8.0X8.500X 39.0T
DEC 11.46,1.81,60.0,43.8,0.,0.,8.16
BCD 3 18.0X7.500X 55.0I
DEC 11.84,5.82,428.16,21.0,0.,0.,18.12
BCD 3 14.0X10.00X 61.0I
DEC 11.92,3.60,242.90,53.7,0.,0.,13.91
BCD 3 16.0X8.500X 58.0I
DEC 12.00,4.72,328.74,30.3,0.,0.,15.86
BCD 3 10.5X9.000X 41.0T
DEC 12.05,2.48,115.4,44.8,0.,0.,10.43
BCD 3 12.0X9.000X 42.0T
DEC 12.35,2.97,165.9,44.2,0.,0.,12.04
BCD 3  9.0X8.750X 42.5T
DEC 12.49,2.05,84.4,49.7,0.,0.,9.16
BCD 3 18.0X7.500X 60.0I
DEC 12.87,5.89,486.69,23.6,0.,0.,18.25
BCD 3 16.0X8.500X 64.0I
DEC 13.23,4.77,386.35,34.2,0.,0.,16.00
BCD 3 18.0X8.750X 64.0I
DEC 13.29,5.35,465.46,35.2,0.,0.,17.87
```

```
BCD 3 14.0X10.00X 68.0I
DEC 13.31,3.75,270.34,60.6,0.,0.,14.06
BCD 3 21.0X8.250X 62.0I
DEC 13.54,6.98,677.75,26.6,0.,0.,20.99
BCD 3 12.0X9.000X 47.0T
DEC 13.81,2.99,185.9,51.1,0.,0.,12.15
BCD 3 13.5X10.00X 47.0T
DEC 13.83,3.41,238.5,57.5,0.,0.,13.45
BCD 3 9.0X11.75X 48.0T
DEC 14.11,1.78,85.3,103.4,0.,0.,9.08
BCD 3 10.5X9.000X 48.0T
DEC 14.11,2.55,137.1,54.7,0.,0.,10.57
BCD 3 14.0X10.00X 74.0I
DEC 14.49,3.73,307.14,66.8,0.,0.,14.19
BCD 3 18.0X8.750X 70.0I
DEC 14.55,5.43,519.91,39.3,0.,0.,18.00
BCD 3 16.0X8.500X 71.0I
DEC 14.70,4.87,423.58,39.0,0.,0.,16.16
BCD 3 12.0X12.00X 50.0T
DEC 14.71,2.54,176.7,101.8,0.,0.,12.00
BCD 3 21.0X8.250X 68.0I
DEC 14.82,6.98,746.75,30.2,0.,0.,21.13
BCD 3 14.0X12.00X 78.0I
DEC 14.84,3.36,286.32,103.5,0.,0.,14.06
BCD 3 13.5X10.00X 51.0T
DEC 15.01,3.39,257.7,64.8,0.,0.,13.53
BCD 3  9.0X11.75X 52.2T
DEC 15.43,1.82,93.9,115.5,0.,0.,9.16
BCD 3 21.0X8.250X 73.0I
DEC 15.87,7.02,809.99,33.1,0.,0.,21.24
BCD 3 15.0X10.50X 54.0T
DEC 15.88,4.03,349.5,67.6,0.,0.,14.91
BCD 3 14.0X12.00X 84.0I
DEC 15.96,3.40,315.49,112.8,0.,0.,14.18
BCD 3 18.0X8.750X 77.0I
DEC 16.02,5.52,590.62,44.3,0.,0.,18.16
BCD 3 16.0X8.500X 78.0I
DEC 16.17,4.95,476.16,43.8,0.,0.,16.32
BCD 3 12.0X12.00X 55.0T
DEC 16.18,2.57,195.2,114.5,0.,0.,12.08
BCD 3 10.5X13.00X 56.0T
DEC 16.47,2.06,136.4,144.8,0.,0.,10.50
BCD 3 24.0X9.000X 76.0I
DEC 16.71,8.03,1071.87,38.2,0.,0.,23.91
BCD 3  9.0X11.75X 57.0T
DEC 16.77,1.85,102.6,127.8,0.,0.,9.24
BCD 3 13.5X10.00X 57.0T
DEC 16.77,3.42,288.9,74.8,0.,0.,13.64
BCD 3 15.0X10.50X 58.0T
DEC 17.07,3.94,371.8,76.6,0.,0.,15.00
BCD 3 16.0X11.50X 88.0I
DEC 17.36,4.32,476.12,92.6,0.,0.,16.16
BCD 3 21.0X9.000X 82.0I
DEC 17.61,6.73,857.38,44.8,0.,0.,20.86
BCD 3 12.0X12.00X 60.0T
DEC 17.64,2.62,213.6,127.0,0.,0.,12.16
```

```
BCD 3 18.0X8.750X 85.0I
DEC 17.75,5.64,667.79,49.7,0.,0.,18.32
BCD 3 15.0X10.50X 62.0T
DEC 18.22,3.90,394.8,84.8,0.,0.,15.08
BCD 3 24.0X9.000X 84.0I
DEC 18.35,8.01,1205.39,44.2,0.,0.,24.09
BCD 3 10.5X13.00X 63.5T
DEC 18.67,2.11,155.8,169.3,0.,0.,10.62
BCD 3 16.0X11.50X 96.0I
DEC 18.89,4.33,518.23,103.6,0.,0.,16.32
BCD 3 12.0X14.00X 65.0T
DEC 19.11,2.47,222.6,187.6,0.,0.,12.13
BCD 3 16.5X11.50X 65.0T
DEC 19.13,4.37,513.0,100.7,0.,0.,16.55
BCD 3 18.0X11.75X 96.0I
DEC 19.15,4.98,672.75,103.4,0.,0.,18.16
BCD 3 15.0X10.50X 66.0T
DEC 19.41,3.90,420.7,92.5,0.,0.,15.15
BCD 3 24.0X9.000X 94.0I
DEC 20.49,8.05,1358.19,51.1,0.,0.,24.29
BCD 3 21.0X9.000X 96.0I
DEC 20.63,6.87,1036.48,54.7,0.,0.,21.14
BCD 3 24.0X12.00X100.0I
DEC 20.73,7.13,1323.64,101.8,0.,0.,24.00
BCD 3 27.0X10.00X 94.0I
DEC 20.75,9.11,1699.13,57.6,0.,0.,26.91
BCD 3 16.5X11.50X 70.5T
DEC 20.76,4.30,551.8,114.9,0.,0.,16.66
BCD 3 10.5X13.00X 71.0T
DEC 20.88,2.18,177.3,193.0,0.,0.,10.73
BCD 3 18.0X11.75X105.0I
DEC 20.95,5.03,741.09,115.5,0.,0.,18.32
BCD 3 12.0X14.00X 72.5T
DEC 21.31,2.48,246.2,217.1,0.,0.,12.24
BCD 3 13.5X14.00X 72.5T
DEC 21.34,2.85,316.3,203.5,0.,0.,13.44
BCD 3 18.0X12.00X 75.0T
DEC 22.08,4.79,696.7,125.2,0.,0.,17.92
BCD 3 16.5X11.50X 76.0T
DEC 22.35,4.26,591.9,128.1,0.,0.,16.75
BCD 3 27.0X10.00X102.0I
DEC 22.41,9.10,1864.14,64.8,0.,0.,27.07
BCD 3 21.0X13.00X112.0I
DEC 22.43,5.77,1091.41,144.9,0.,0.,21.00
BCD 3 18.0X11.75X114.0I
DEC 22.77,5.13,831.81,127.8,0.,0.,18.48
BCD 3 24.0X12.00X110.0I
DEC 22.80,7.19,1470.20,114.6,0.,0.,24.16
BCD 3 12.0X14.00X 80.0T
DEC 23.54,2.51,271.6,246.3,0.,0.,12.36
BCD 3 18.0X12.00X 80.0T
DEC 23.54,4.76,741.0,137.7,0.,0.,18.00
BCD 3 13.5X14.00X 80.0T
DEC 23.72,2.91,351.4,229.0,0.,0.,13.54
BCD 3 30.0X10.50X108.0I
DEC 24.38,10.52,2437.71,67.6,0.,0.,29.82
```

```
BCD 3 24.0X12.00X120.0I
DEC 24.91,7.28,1626.96,127.0,0.,0.,24.31
BCD 3 18.0X12.00X 85.0T
DEC 24.99,4.74,784.70,150.3,0.,0.,18.08
BCD 3 27.0X10.00X114.0I
DEC 25.01,9.15,2096.78,74.8,0.,0.,27.28
BCD 3 15.0X13.00X 86.0T
DEC 25.32,3.23,471.0,275.1,0.,0.,14.94
BCD 3 21.0X15.00X127.0I
DEC 25.45,5.89,1228.71,169.3,0.,0.,21.24
BCD 3 30.0X10.50X116.0I
DEC 25.93,10.39,2625.62,76.6,0.,0.,30.00
BCD 3 13.5X14.00X 88.5T
DEC 26.05,2.97,391.8,259.4,0.,0.,13.66
BCD 3 24.0X14.00X130.0I
DEC 26.42,6.91,1685.85,187.6,0.,0.,24.25
BCD 3 18.0X12.00X 91.0T
DEC 26.77,4.77,844.0,163.9,0.,0.,18.16
BCD 3 30.0X10.50X124.0I
DEC 27.53,10.34,2820.95,84.9,0.,0.,30.16
BCD 3 15.0X15.00X 95.0T
DEC 27.95,3.26,520.4,312.3,0.,0.,15.06
BCD 3 21.0X13.00X142.0I
DEC 28.58,6.03,1403.74,193.0,0.,0.,21.46
BCD 3 33.0X11.50X130.0I
DEC 29.15,11.52,3598.42,100.7,0.,0.,33.10
BCD 3 30.0X10.50X132.0I
DEC 29.28,10.37,3033.51,92.5,0.,0.,30.30
BCD 3 24.0X14.00X145.0I
DEC 29.34,6.92,1899.01,217.2,0.,0.,24.29
BCD 3 16.5X15.75X100.0T
DEC 29.40,3.67,683.6,345.8,0.,0.,16.50
BCD 3 27.0X14.00X145.0I
DEC 30.01,7.97,2390.22,203.5,0.,0.,26.88
BCD 3 15.0X15.00X105.0T
DEC 30.89,3.31,578.0,354.0,0.,0.,15.19
BCD 3 33.0X11.50X141.0I
DEC 31.36,11.28,3881.91,114.9,0.,0.,33.31
BCD 3 24.0X14.00X160.0I
DEC 32.33,7.00,2138.32,246.3,0.,0.,24.72
BCD 3 16.5X15.75X110.0T
DEC 32.36,3.71,754.1,391.2,0.,0.,16.63
BCD 3 27.0X14.00X160.0I
DEC 33.12,8.07,2671.83,229.0,0.,0.,27.08
BCD 3 33.0X11.50X152.0I
DEC 33.62,11.39,4258.86,128.1,0.,0.,33.50
BCD 3 36.0X12.00X150.0I
DEC 33.79,12.55,4870.24,125.2,0.,0.,35.84
BCD 3 18.0X16.50X115.0T
DEC 33.86,4.02,935.8,435.5,0.,0.,17.94
BCD 3 16.5X15.75X120.0T
DEC 35.26,3.73,822.5,437.2,0.,0.,16.75
BCD 3 30.0X15.00X172.0I
DEC 35.83,8.98,3541.84,275.0,0.,0.,29.88
BCD 3 36.0X12.00X160.0I
DEC 35.89,12.53,5230.68,137.7,0.,0.,36.00
```

```
BCD 3 18.0X16.50X122.5T
DEC 36.01,4.04,994.3,472.3,0.,0.,18.03
BCD 3 27.0X14.00X177.0I
DEC 36.75,8.19,3013.34,259.5,0.,0.,27.31
BCD 3 36.0X12.00X170.0I
DEC 37.96,12.53,5607.60,150.3,0.,0.,36.16
BCD 3 18.0X16.50X130.0T
DEC 38.28,4.07,1059.2,510.3,0.,0.,18.12
BCD 3 30.0X15.00X190.0I
DEC 39.48,9.05,3967.07,312.3,0.,0.,30.12
BCD 3 36.0X12.00X182.0I
DEC 40.69,12.62,6071.86,163.9,0.,0.,36.32
BCD 3 18.0X16.50X140.0T
DEC 41.16,4.07,1133.3,563.7,0.,0.,18.25
BCD 3 33.0X15.75X200.0I
DEC 42.21,10.25,5197.69,345.9,0.,0.,33.00
BCD 3 36.0X12.00X194.0I
DEC 43.43,12.69,6521.07,177.7,0.,0.,36.48
BCD 3 30.0X15.00X210.0I
DEC 43.65,9.15,4448.55,354.0,0.,0.,30.38
BCD 3 18.0X16.50X150.0T
DEC 44.09,4.13,1222.7,612.6,0.,0.,18.36
BCD 3 33.0X15.75X220.0I
DEC 46.20,10.20,5668.24,391.2,0.,0.,33.25
BCD 3 36.0X16.50X230.0I
DEC 48.56,11.10,6967.84,435.5,0.,0.,35.88
BCD 3 33.0X15.75X240.0I
DEC 50.27,10.29,6274.16,437.2,0.,0.,33.50
BCD 3 36.0X16.50X245.0I
DEC 51.56,11.14,7479.32,472.4,0.,0.,36.06
BCD 3 36.0X16.50X260.0I
DEC 54.79,11.20,8015.06,510.3,0.,0.,36.24
BCD 3 36.0X16.50X280.0I
DEC 58.73,11.24,8741.46,563.8,0.,0.,36.50
BCD 3 36.0X16.50X300.0I
DEC 63.01,11.37,9493.02,612.6,0.,0.,36.72
BCD 3 THERE IS NO BEAM
DEC -1.0,-1.0,-1.0,-1.0,-1.0,-1.0,
END 0
```

APPENDIX C

PROGRAM FOR SELECTING SCANTLINGS AND PLATING

```
        SAP M885-721-PROGRAM

        LST OFF
        PRG OFF
COMMON  SYN /25
MICMDL  SYN /127
  SQRT  SYN /356
  COS   SYN /423
  SIN   SYN /424
  BLOCK SYN /520
  WOT   SYN /1376
        ORG /10570
  START CLA HANDL                 0, 0, 15
        COM
        STD INDAA                 0, 0, -16
        STD INDAB
        STD INDAC
        STD INDAD
        STD INDAE
        STD INDAF
        STD INDAG
        STD INDAH
        STD INDAI
        STD INDAJ
        CLA HANDL+1               0, 0, 31
        COM
        STD INDBA                 0, 0, -32
        STD INDBB
        STD INDBC
        STD INDBD
        STD INDBE
```

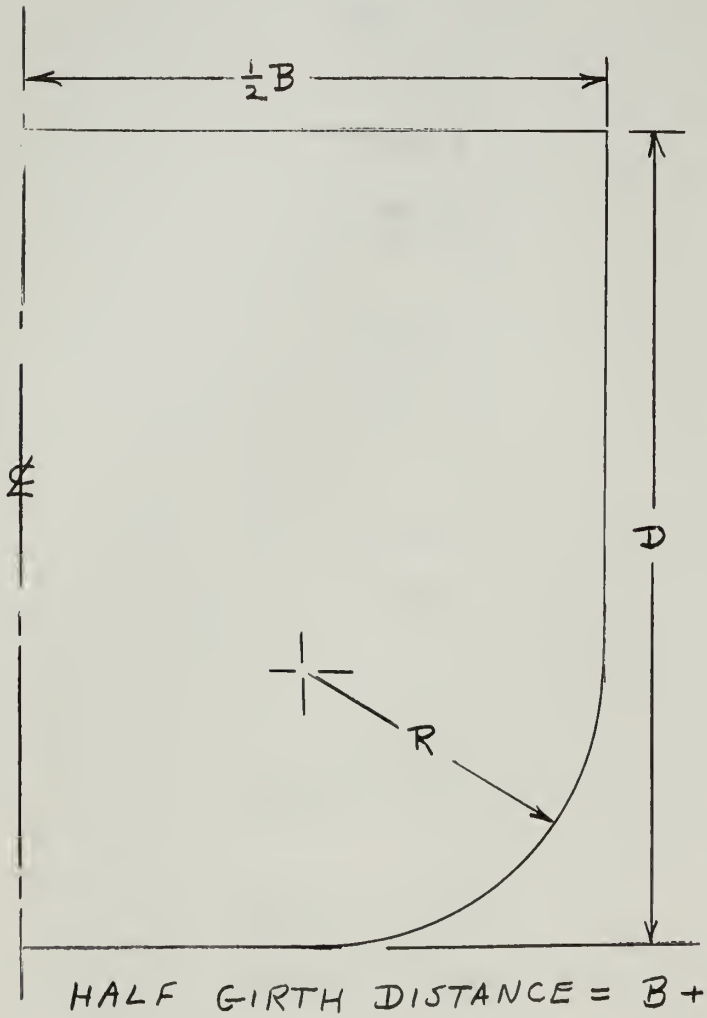
```
STD INDBF
STD INDBG
STD INDBH
STD INDBI
STD INDBJ
STD INDBK
STD INDBL
STD INDBM
STD INDBN
STD INDBO
STD INDBP
STD INDBQ
STD INDBR
STD INDBS
STD INDBT
STD INDBU
STD INDBV
STD INDBW
CLA HANDL+2                    0, 0, 9
COM
STD INDCA                      0, 0, -10
CLA HANDL+3                    0, 0, 2
COM
STD INDDA                      0, 0, -3
STD INDDB
STD INDDC

REM CONVERSION OF UNITS
```

LDQ INPUT	D (ft)
FMP CONST+5	12
STO INPUT	D (in)
LDQ INPUT+1	B (ft)
FMP CONST+5	12
STO INPUT+1	B (in)
LDQ INPUT+2	R (ft)
FMP CONST+5	12
STO INPUT+2	R (in)
LDQ INPUT+3	F (ft)
FMP CONST+5	12
STO INPUT+3	F (in)
LDQ INPUT+4	W (ft)
FMP CONST+5	12
STO INPUT+4	W (in)
LDQ INPUT+12	M_1^+ (ft-TONS)
FMP CONST+5	12
STO INPUT+12	M_1^+ (in-TONS)
LDQ INPUT+13	M_1^- (ft-TONS)
FMP CONST+5	12
STO INPUT+13	M_1^- (ft-TONS)
LDQ INPUT+14	H_0 (ft)
FMP CONST+5	12
STO INPUT+14	H_0 (in)
LDQ INPUT+12	M_1^+ (in-TONS)
FMP CONST+29	2240
STO INPUT+12	M_1^+ (in-LBS)
LDQ INPUT+13	M_1^- (in-TONS)
FMP CONST+29	2240
STO INPUT+13	M_1^- (in-lbs)

FIGURE 2

Parameters Which Describe the Hull Shape



HALF GIRTH DISTANCE $= B + D - 2R + \frac{\pi}{2} R$

$= B + D - R(2 - \pi/2)$

$= B + D - 0.4292R$

HALF SCANTLING SPACING:

$$\frac{b_0}{2} = \frac{1}{n_0}(B + D - 0.4292R) \qquad (1)$$

SUCCESIVE SCANTLING SPACINGS

$$bn = b_0 n_0, \quad b = b_0 \frac{n_0}{n} \qquad (2)$$

```
REM CALCULATION OF CONSTANT GEOMETRICAL PARAMETERS
EFM                                   ENTER FLOATING TRAP MODE
CLA INPUT+1                           B
FDP CONST+2                           2
STQ ASIDE+5                           ½B
CLA ASIDE+5                           ½B
FSB INPUT+2                           R
STO ASIDE+9                           ½B-R
FAD ASIDE+5                           ½B
FDP CONST+2                           2
STQ ASIDE+7                           ½(B-R)
CLA INPUT+12                          M_i^+
STO REMEM+5                           A_1 (min)
CLA CONST+1                           1.0
STO TEMP+18
REM CALCULATION OF INITIAL LONGITUDINAL SPACING
LDQ INPUT+2                           R
FMP CONST+4                           -0.4292 = -2+π/2
FAD INPUT                             D
FAD INPUT+1                           B
FDP INPUT+8                           n
STQ ASIDE+8                           ½b_o = 1/n_o (B+D-0.4292R)      (1)
FMP CONST+2                           2
STO ASIDE+1                           b_o
STO ASIDE+2                           b = b_o
CLA INPUT+8                           n_o
STO ASIDE                             n = n_o
REM CALCULATION OF ESTIMATED MOMENTS OF INERTIA
```

Initial estimate of total hull moment of inertia:

1. Assume neutral axes to be located at mid depth
2. Assume primary bending stresses at the extreme fibers to be 20,000 psi.

$$\sigma = \frac{Mc}{I} \qquad I = \frac{Mc}{\sigma} = \frac{M}{20000} \times \frac{D}{2} = \frac{MD}{40000}$$

Effective width of plating in compression:

Karman-Sechler formula as quoted in ref. 3.

$$\frac{\lambda}{t} = 1.70\sqrt{E/\sigma_{yp}}$$

```
      LDQ INPUT+12                  M_i^+
      FMP INPUT                     D
      FDP CONST+6                   40000.0
      STQ REMEM                     I_i^+ = M_i^+ D/40000.0  (FIRST EST)
      LDQ INPUT+13                  M_i^-
      FMP INPUT                     D
      FDP CONST+6                   40000.0
      STQ REMEM+1                   I_i^- = M_i^- D/40000.0 (FIRST EST)
      REM FIRST ESTIMATE OF LOCATION OF NEUTRAL AXES
      CLA INPUT                     D
      FDP CONST+2                   2
      STQ REMEM+2                   z_c^+ = D/2   (FIRST ESTIMATE)
      STQ REMEM+3                   z_c^- = D/2   (FIRST ESTIMATE)
      REM CALCULATION OF EFFECTIVE WIDTH (KARMAN SECHLER)
      CLA INPUT+18                  E
      FDP INPUT+17                  σ_yp^-
      STQ TEMP                      E/σ_yp^-
      CLA TEMP                      E/σ_yp^-
      TSX SQRT,4
      HTR                           ERROR STOP
      STO TEMP                      sqrt(E/σ_yp^-)
      LDQ TEMP                      sqrt(E/σ_yp^-)
      FMP CONST+7                   1.70
      STO ASIDE+10                  x/t = 1.70 sqrt(E/σ_yp^-)      (4)
      REM CALCULATIONS OF PARAMETERS OF LONGITUDINAL SPACING
INSAA LDQ ASIDE+2                   b
      FMP ASIDE+2                   b
      STO ASIDE+3                   b^2
```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98

Effective breadth: (ref. 3)

Curve (a) of Figure 11 (multiple webs under uniform load) is used to determine $\lambda \leq b$

From (ref. 4) p. 2-31: assume an equation of the following form:

$Y = \frac{\lambda}{b}$, $X = \frac{cL}{B}$ $\quad c = 0.578$ (FIXED ENDS)

$$Y = a_1 + a_2(X-1) + a_3(X-1)(X-2) + a_4(X-1)(X-2)(X-3)$$

X	Y
1	0.41
	0.32
2	0.73
	−0.065
	0.17
	0.00
3	0.92
	−0.065
	0.06
4	0.98

$a_1 = 0.41$

$a_2 = 0.32$

$a_3 = -0.065$

$a_4 = 0$

$$Y = 0.41 + 0.32(X-1) - 0.065(X-1)(X-2)$$

$$= -0.04 + 0.515X - 0.065X^2$$

WHERE $0.5 < X < 4.5$

$$\frac{\lambda}{b} = -0.04 + 0.29767\,a/b - 0.02171546\,\frac{a^2}{b^2}$$

$$\lambda = -0.046 + 0.29767a - 0.02171546\,a^2/b \qquad (5)$$

for $a/b \geq 7.7855$, $\lambda = b$

```
      FDP CONST+5                    12.0
      FMP ASIDE+2                    b
      STO ASIDE+4                    b^3/12
      CLA ASIDE+2                    b
      FDP CONST+2                    2
      STQ ASIDE+8                    b/2
      REM EFFECTIVE BREADTH (SCHADE,SNAME TRANS.11-51)
      LDQ ASIDE+2                    b
      STQ ASIDE+11                   λ=b
      FMP CONST+8                    7.7855
      LDQ INPUT+5                    a
      TLQ INSAB ---                  if a < 7.7855b     λ<b
      TRA INSAC ---                  if a ≥ 7.7855b     λ=b
INSAB LDQ ASIDE+2 <-                 b
      FMP CONST+9                    -0.04
      STO TEMP                       -0.04b
      LDQ INPUT+5                    a
      FMP CONST+10                   0.29767
      FAD TEMP                       -0.04b
      STO TEMP                       -0.04b+0.29767a
      LDQ INPUT+5                    a
      FMP INPUT+5                    a
      FDP ASIDE+2                    b
      FMP CONST+11                   -0.02171546
      FAD TEMP                       -0.04b+0.29767a
      STO ASIDE+11                   λ=-0.04b+0.29767a
                                     -0.02171546a^2/b   (5)
INSAC LXD NIX,1 <---                 RESET INDEX 1
      REM NUMBERING OF LOCATIONS, KEEL IS LOCATION ZERO
```

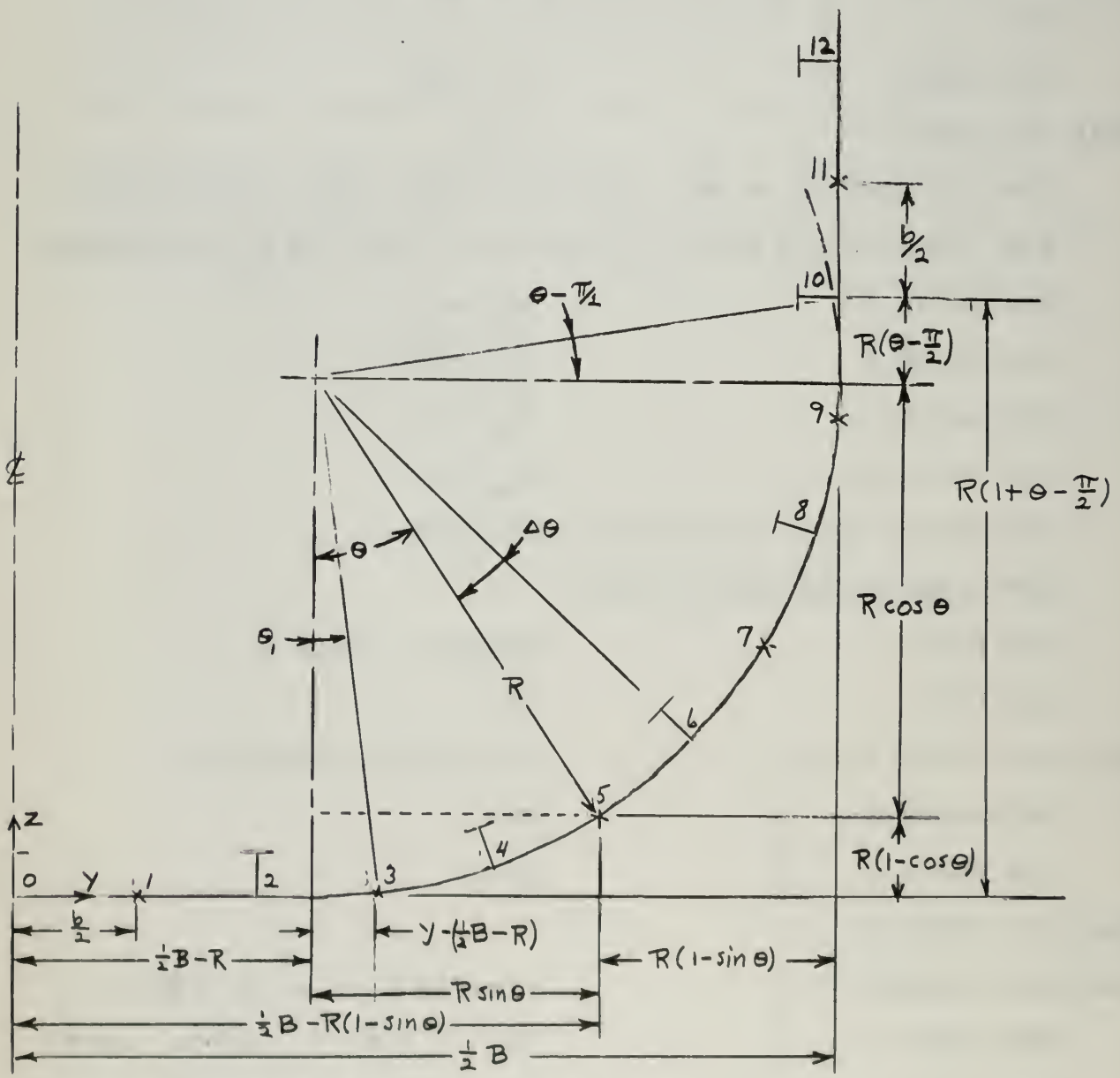
Locations are numbered consecutively from the keel (o) around the girth of the hull to the centerline at the deck, (n). The next two locations beyond the one designated (n) are arbitrarily given coordinates (-1, -1). This was done to assist in transferring out of the numerous loops found later in the program. The above simplifies indexing procedures since all other coordinates are positive.

```
      CLA NIX                    0.0
INSAD STO LOC,1                  c = 0, 1, 2, . . . , n
      FAD CONST+1                1.0
INDAA TXI INSAE,1        (-16)
INSAE CAS ASIDE                  COMPARE c WITH n
      TRA INSAF                  if c > n, LEAVE LOOP
      NOP
      TRA INSAD                  if c ≤ n
INSAF CLA CONST                  -1.0
      REM COORDINATES OF TWO LOCATIONS BEYOND THE LAST PERTINENT
      REM LOCATION ARE SET AT MINUS ONE TO FACILITATE PROGRAMMING
      STO LOC+1,1                z_{n+1} = -1.0
      STO LOC+2,1                y_{n+1} = -1.0
      STO LOC+17,1               z_{n+2} = -1.0
      STO LOC+18,1               y_{n+2} = -1.0
      REM CALCULATION OF LOCATION COORDINATES
      REM COORDINATES ALONG BOTTOM
      LXD NIX,1                  RESET INDEX 1
      CLA NIX                    0.0
INSAG STO LOC+2,1                y = 0, b/2, b, 3b/2, 2b, . . .
      FAD ASIDE+8                b/2
      STZ LOC+1,1                z = 0
INDAB TXI INSAH,1        (-16)
INSAH CAS ASIDE+9                COMPARE y WITH ½B-R
      TRA INSAI                  if y > ½B-R, LEAVE LOOP
      NOP
      TRA INSAG                  if y ≤ ½B-R
      REM COORDINATES AT TURN OF BILGE
```


60

FIGURE 3

Coordinates along the bottom, turn of the bilge and side of the hull



$Y < \frac{1}{2}B - R$: $Y = c\frac{b}{2}$ $\quad z = 0$ $\quad c = 1, 2, 3, 4, \ldots$

$0 < \theta < \frac{\pi}{2}$: $Y = \frac{1}{2}B - R(1 - \sin\theta)$ $\quad z = R(1 - \cos\theta)$ (6) (7)

$\frac{\pi}{2} < \theta$, $z < D$: $Y = \frac{1}{2}B$ $\quad z = R + R(\theta - \frac{\pi}{2}) + c\frac{b}{2}$ $\quad c = 1, 2, 3, 4, \ldots$ (8) (9)

58

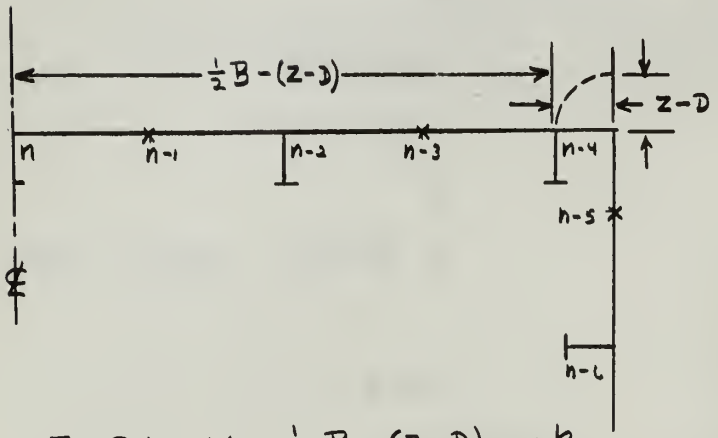
```
INSAI FSB ASIDE+9<      ½B-R
      FDP INPUT+2       R
      STQ TEMP          θ1 = 1/R[Y-(½B-R)]
      CLA ASIDE+8       ½b
      FDP INPUT+2       R
      STQ TEMP+1        Δθ = b/2R
INSAJ LDQ CONST+12<     1.5708 = ½π
      CLA TEMP          θ
      TLQ INSAK---      if θ>½π, LEAVE LOOP
      TSX SIN,4
      STO TEMP+2        SIN θ
      CLA TEMP          θ
      TSX COS,4
      STO TEMP+3        COS θ
      CLA CONST+1       1.0
      FSB TEMP+3        COS θ
      STO TEMP+4        1-COS θ
      LDQ TEMP+4        1-COS θ
      FMP INPUT+2       R
      STO LOC+1,1       z=R(1-COS θ)    (7)
      CLA TEMP+2        SIN θ
      FAD CONST         -1.0
      STO TEMP+4        SIN θ-1
      LDQ TEMP+4        SIN θ-1
      FMP INPUT+2       R
      FAD ASIDE+5       ½B
      STO LOC+2,1       Y=½B+R(SIN θ-1)  (6)
      CLA TEMP          θ
```

62 ↓62

60

FIGURE 4

Coordinates along the Deck

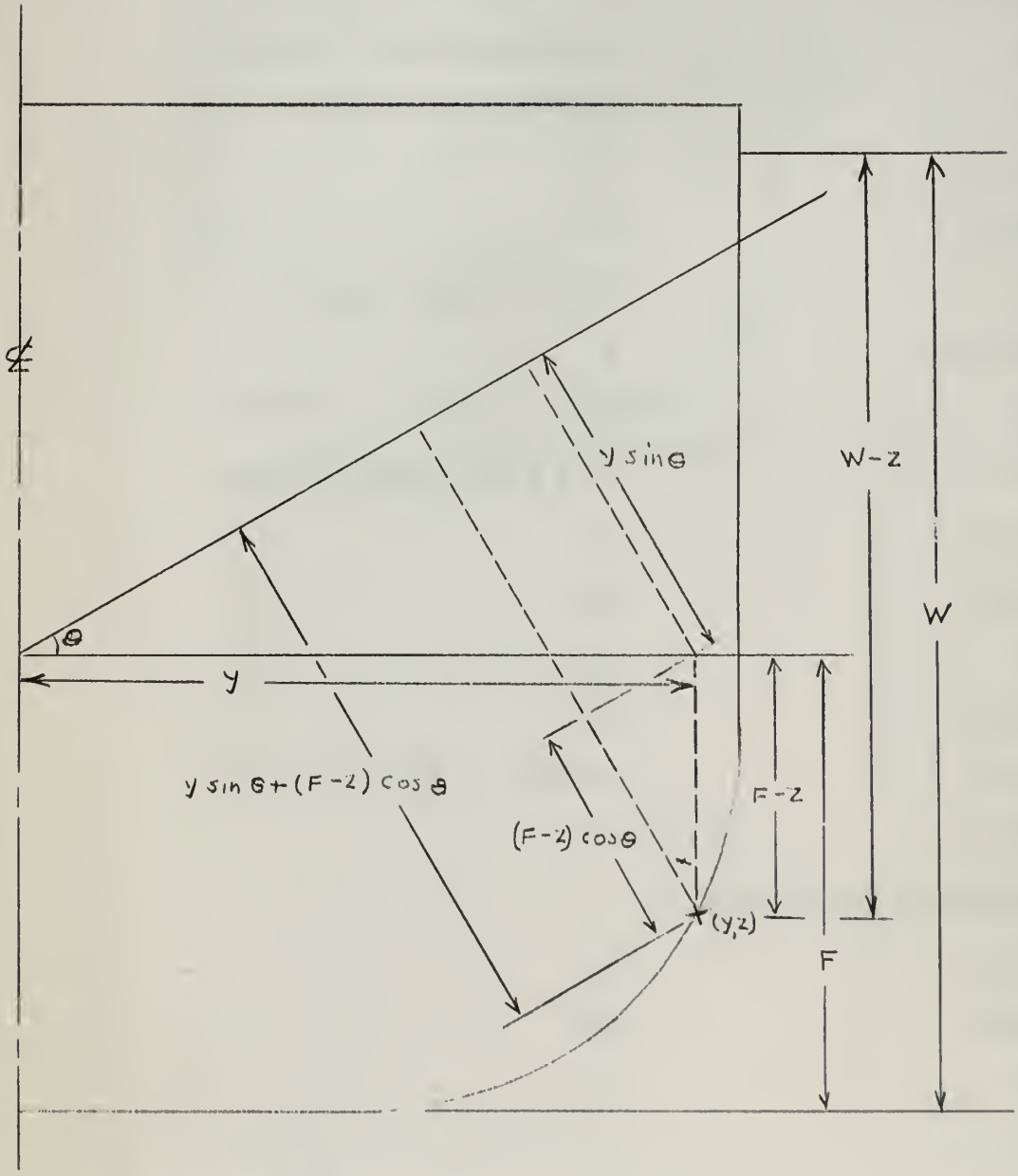


$$Z = D: \quad Y = \tfrac{1}{2}B - (Z-D) - c\,\tfrac{b}{2} = \tfrac{1}{2}B + D - Z - c\,\tfrac{b}{2} \qquad \left.\right\} \; c = 1, 2, 3, \ldots \qquad (10)$$

```
      FAD TEMP+1                               ΔΘ
      STO TEMP                                 Θ
INDAC TXI INSAJ,1                (-16)
      REM COORDINATES ALONG SIDE OF HULL
INSAK FSB CONST+12                             1.5708 = π/2
      STO TEMP                                 Θ - π/2
      LDQ TEMP                                 Θ - π/2
      FMP INPUT+2                              R
      FAD INPUT+2                              R
      STO TEMP                                 z = R + R(Θ - π/2)  (9)
INSAL CLA TEMP                                 z
      LDQ INPUT                                D
      TLQ INSAM                                if z > D, LEAVE LOOP
      STO LOC+1,1                              z
      FAD ASIDE+8                              ½b
      STO TEMP                                 z
      CLA ASIDE+5                              B/2
      STO LOC+2,1                              y = B/2    (8)
INDAD TXI INSAL,1                (-16)
      REM COORDINATES ALONG DECK
INSAM CLA INPUT                                D
      FAD ASIDE+5                              B/2
      FSB TEMP                                 z
      STO TEMP                                 Y = ½B + D - z     (10)
INSAN CLA TEMP                                 Y
      TMI INSAO                                if Y < 0, LEAVE LOOP
      STO LOC+2,1                              Y
      FSB ASIDE+8
```

FIGURE 5

Hydrostatic Heads



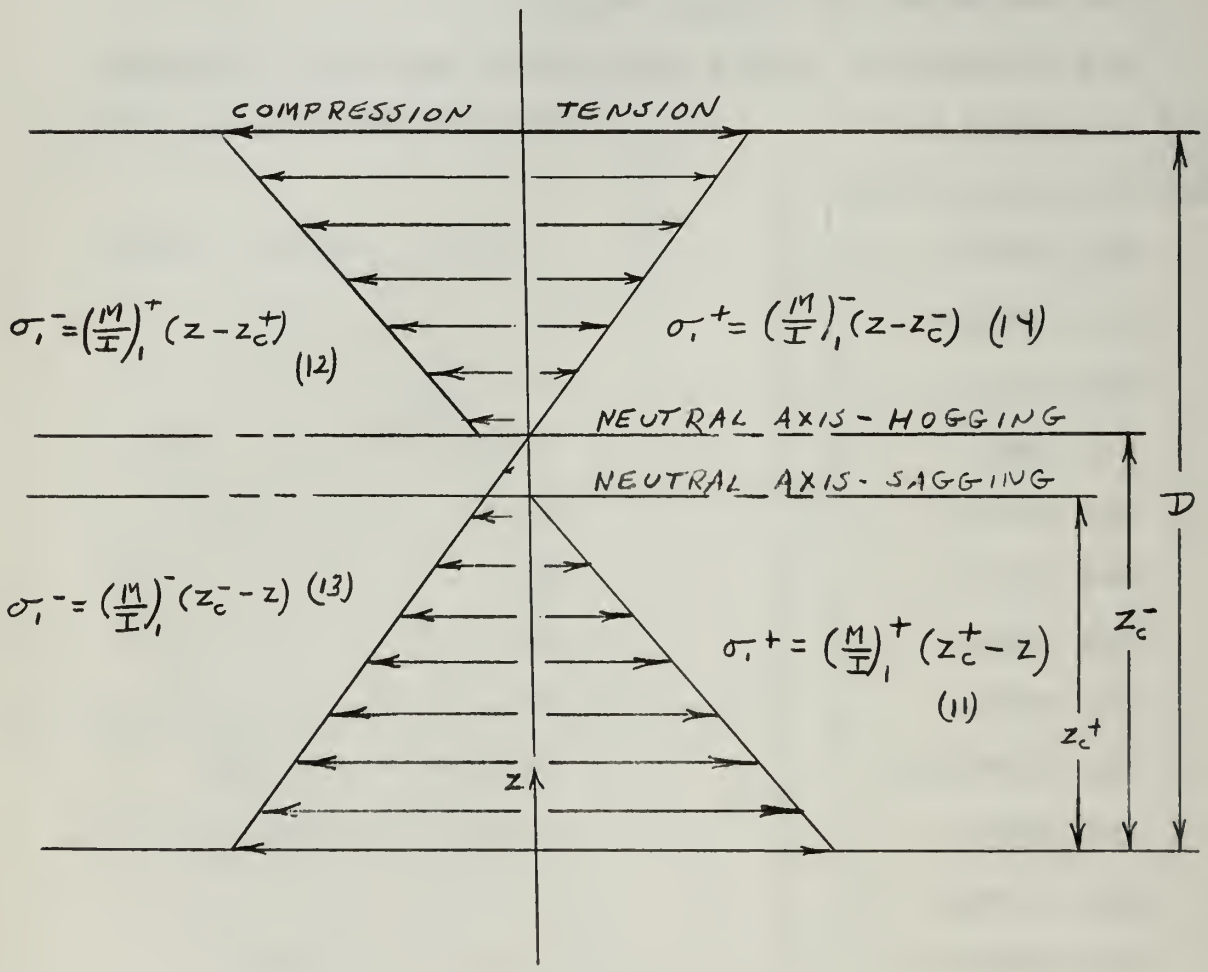
$$H_w = W - z \qquad (10)$$

$$H_\theta = y \sin\theta + (F - z)\cos\theta \qquad (11)$$

```
                                                    62.   62
        STO TEMP                                      |     |     Y
        CLA INPUT                                     |     |     D
        STO LOC+1,1                                   |     |     Z=D
INDAE   TXI INSAN,1                                   |     |     (-16)
        REM BEGINNING OF GENERAL PROGRAM              |     |
        REM CALCULATION OF MAX HYDROSTATIC HEAD EACH LOCATION
INSAO   LXD NIX,1                                     |     |     RESET INDEX 1
INSAP   CLA LOC+1,1                                   |     |     Z
        TMI INSAS                                     |     |     if Z=-1 LEAVE LOOP
        CLA INPUT+4                                   |     |     W
        FSB LOC+1,1                                   |     |     Z
        STO TEMP                                      |     |     Hw=W-Z          (9)
        CLA INPUT+3                                   |     |     F
        FSB LOC+1,1                                   |     |     Z
        STO TEMP+1                                    |     |     F-Z
        LDQ TEMP+1                                    |     |     F-Z
        FMP CONST+13                                  |     |     0.8660 = COS 30°
        STO TEMP+1                                    |     |     0.8660(F-Z)
        LDQ LOC+2,1                                   |     |     Y
        FMP CONST+14                                  |     |     0.50 = SIN 30°
        FAD TEMP+1                                    |     |     0.8660(F-Z)     (10)
        CAS INPUT+14                                  |     |     COMPARE Ho WITH Hw
        TRA INSAQ                                     |     |     if Ho > Hw
        NOP                                           |     |
        CLA INPUT+14                                  |     |     Hw if Hw ≥ Ho
INSAQ   CAS TEMP                                      |     |     COMPARE LARGER H WITH Ho
        TRA INSAR                                     |     |     if Ho > Ho AND Hw
        NOP                                           |     |
                                                      |     |
                                                      |     |  64
                                                   66 |  66 |  66
```

FIGURE 6

Distribution of Stresses due to Ship Bending Moments



```
                                                    Ho IF Ho > He AND Hw
      CLA TEMP                                      THE LARGEST VALUE OF H
INSAR STO LOC+15,1
INDAF TXI INSAP,1                    (-16)
      REM CALCULATION OF SHIP (PRIMARY) BENDING STRESSES
INSAS LXD NIX,1                                     RESET INDEX 1
      CLA INPUT+12                                  M_1^+
      FDP REMEM                                     I_1^+
      STQ REMEM+10                                  (M/I)_1^+
      CLA INPUT+13                                  M_1^-
      FDP REMEM+1                                   I_1^-
      STQ REMEM+11                                  (M/I)_1^-
      REM STRESSES DUE TO POSITIVE SHIP BENDING MOMENT
INSAT CLA REMEM+2                                   z_c^+
      FSB LOC+1,1                                   z
      TMI INSAU                                     if z > z_c^+, LEAVE LOOP
      STO TEMP                                      z_c^+ - z
      LDQ TEMP                                      z_c^+ - z
      FMP REMEM+10                                  (M/I)_1^+
      STO LOC+8,1                                   σ_1^+ = (M/I)_1^+ (z_c^+ - z)    z_c^+ > z
                                                                                     (11)
INDAG TXI INSAT,1                    (-16)
INSAU CLA LOC+1,1                                   z
      TMI INSAV                                     if z = -1, LEAVE LOOP
      FSB REMEM+2                                   z_c^+
      STO TEMP                                      z - z_c^+
      LDQ TEMP                                      z - z_c^+
      FMP REMEM+10                                  (M/I)_1^+
      STO LOC+9,1                                   σ_1^- = (M/I)_1^+ (z - z_c^+)    z_c^+ < z
                                                                                     (12)
INDAH TXI INSAU,1                    (-16)
```

Bryan Buckling criteria for plates loaded in end compression, simple support all edges.

$$\sigma_{cr} = \frac{K\pi^2 E t^2}{12(1-\mu^2)b^2}$$

$a/b > 1.0 : K = 4$

$a/b < 1.0 : K > 4$

$E = 30 \times 10^6$ psi

$\mu = 0.3$

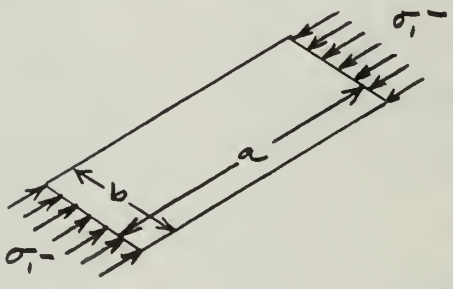
$$\sigma_{cr} = \frac{4 \times 9.87 \times 30 \times 10^6 \, t^2}{12(1-0.09)b^2} = 108.46155 \times 10^4 \frac{t^2}{b^2}$$

$$t \geq \frac{b\sqrt{\sigma_{cr}}}{10414}, \quad (K = 4)$$

SINCE LOAD FACTORS OF SAFETY ARE USED

LET $\sigma_1^- = \sigma_{cr}$

$$\therefore t \geq \frac{b\sqrt{\sigma_1^-}}{10414}$$



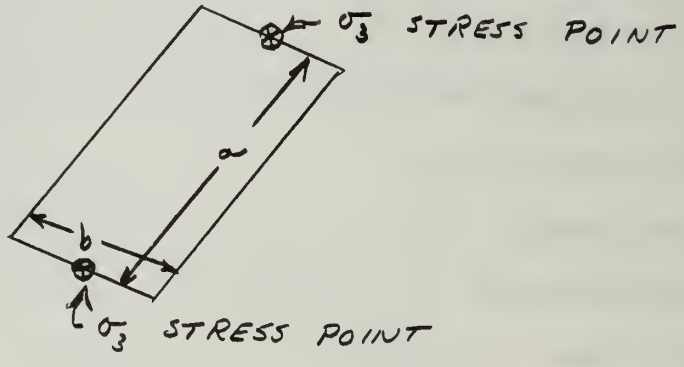
```
      REM STRESSES DUE TO NEGATIVE SHIP BENDING MOMENT
INSAV LXD NIX,1      RESET INDEX 1
INSAW CLA REMEM+3    z_c^-
      FSB LOC+1,1    z
      TMI INSAX      if z > z_c^-
      STO TEMP       z_c^- - z
      LDQ TEMP       z_c^- - z
      FMP REMEM+11   (M/I)_1^-
      STO LOC+9,1    σ_1^- = (M/I)_1^- (z_c^- - z)   z_c^- > z   (13)
INDAI TXI INSAW,1-16
INSAX CLA LOC+1,1    z
      TMI INSAY      if z = -1 LEAVE LOOP
      FSB REMEM+3    z_c^-
      STO TEMP       z - z_c^-
      LDQ TEMP       z - z_c^-
      FMP REMEM+11   (M/I)_1^-
      STO LOC+8,1    σ_1^+ = (M/I)_1^- (z_c^- - z)   z_c^- < z   (14)
INDAJ TXI INSAX,1-16
      REM SELECTION OF HULL PLATING BRYAN BUCKLING CRITERIA
INSAY LXD NIX,3      RESET INDEX 1
INSAZ CLA LOC+17,1   z_p
      TMI INSBC      if z_p = -1, LEAVE LOOP
      CLA LOC+25,1   σ_1^-
      TSX SQRT,4
      HTR            ERROR STOP
      FDP CONST+15   10414.0
      FMP ASIDE+2    b
      STO TEMP       t(min) = b √σ_1^- / 10414.0
```

Tertiary Stress Calculations (ref. 5). Stress due to lateral load on plate.

$$\sigma_3 = \frac{1}{2} K \rho H \frac{b^2}{\tau^2} \times \frac{1}{144} \qquad \frac{a}{b} > 1.6 \quad K = 0.685$$

$$= \frac{1}{2} \times 0.685 \times 64 \left(\frac{lb}{ft^3}\right) \times H\,(in) \times \frac{1}{1728} \left(\frac{ft^3}{in^3}\right) \frac{b^2}{\tau^2} = 0.0127\, H \frac{b^2}{\tau^2}$$

$$\sigma_3 = 0.0127\, H \frac{b^2}{\tau^2} \qquad (16)$$



Stress schedule in plating midway between longitudinals σ_2 is specified by INPUT+19.

$$\sigma_3 = \sigma_3^+ = \sigma_3^-$$

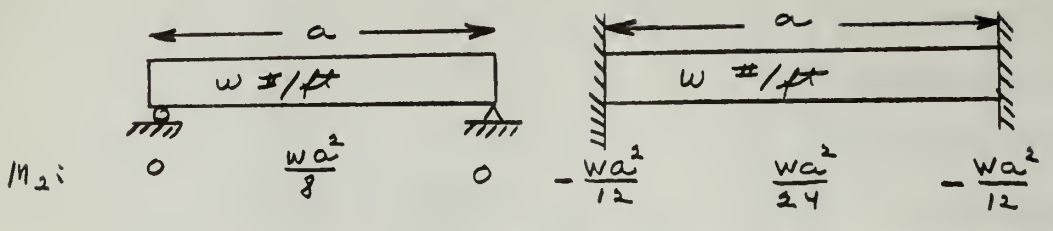
$$\sigma_1^+ + \sigma_2 + \sigma_3 \leq \sigma_{YP}^+ \qquad (17)$$

$$\sigma_1^- - \sigma_2 + \sigma_3 \leq \sigma_{YP}^- \qquad (18)$$

```
      REM SELECTION OF PLATING THICKNESS FROM STD STOCK
INSBA CLA PLATE,2          PLATE DESIG (LB/FT²)
      TMI INDDC+2          if LB/FT² = -1, SKIP
      CLA TEMP             t (min)
      CAS PLATE+1,2        COMPARE t (min) WITH t (AVAILABLE
INDDA TXI INSBA,2          (-3) if t (min) > t (AVAIL)
      REM TERTIARY STRESS CALCULATION
      NOP
INSBB LDQ ASIDE+3          b²
      FMP LOC+31,1         Hp
      FDP PLATE+2,2        t²
      FMP CONST+16         0.0127
      STO LOC+26,1         σ3 = 0.0127 Hp b²/t²        (16)
      STO LOC+58,1         σ3
      REM STRESS SCHEDULE BETWEEN LONGITUDINALS
      FAD LOC+24,1         σ1+
      FAD INPUT+19         σ2
      CAS INPUT+16         COMPARE σ1+ + σ2 + σ3 WITH σyp+   (17)
INDDB TXI INSBB,2          (-3)
      NOP
      CLA LOC+25,1         σ1-
      FAD LOC+26,1         σ3
      FSB INPUT+19         σ2
      CAS INPUT+17         COMPARE σ1- - σ2 + σ3 WITH σyp-
INDDC TXI INSBB,2          (-3)                        (18)
      NOP
      CLA PLATE,2          PLATE DESIGNATION (LB/FT²)
      STO LOC+19,1         "  "  (LB/FT²)
```

```
                    68 | 68
      CLA PLATE+1,2    |                    t
      STO LOC+20,1     |                    t
      STO LOC+52,1     |                    t
      CLA PLATE+2,2    |                    t^2
      STO LOC+21,1     |                    t^2
      LXD NIX,2        |                    RESET INDEX 2
INDBA TXI INSAZ,1-     |          (-32)
INSBC LXD NIX,3 <--    |                    RESET INDICES 1 AND 2
      REM PLATE THICKNESSES TO BE ASSOCIATED WITH SCANTLINGS
      LDQ LOC+20       |                    t
      STQ LOC+7        |                    t
      FMP ASIDE+10     |                    λ⁻/t
      CAS ASIDE+2      |                    COMPARE λ⁻ WITH b
      CLA ASIDE+2      |                    b
      NOP              |
      STO LOC+14       |                    THE SMALLER OF λ⁻ OR b
INDBB TXI INSBD,1-     |          (-32)
INSBD CLA LOC+1,1 <    |                    z_s
      TMI INSBF--      |                    if z_s = -1 LEAVE LOOP
      CLA LOC-12,1     |                    t
      FAD LOC+20,1     |                    t
      FDP CONST+2      |                    2
      STQ LOC+7,1      |                    t
      STQ LOC+39,1     |                    t
      FMP ASIDE +10    |                    λ⁻/t
      CAS ASIDE +2     |                    COMPARE λ⁻/t WITH b
      CLA ASIDE +2     |                    b
      NOP              |
                    73 | 73
```

Secondary Bending Moments

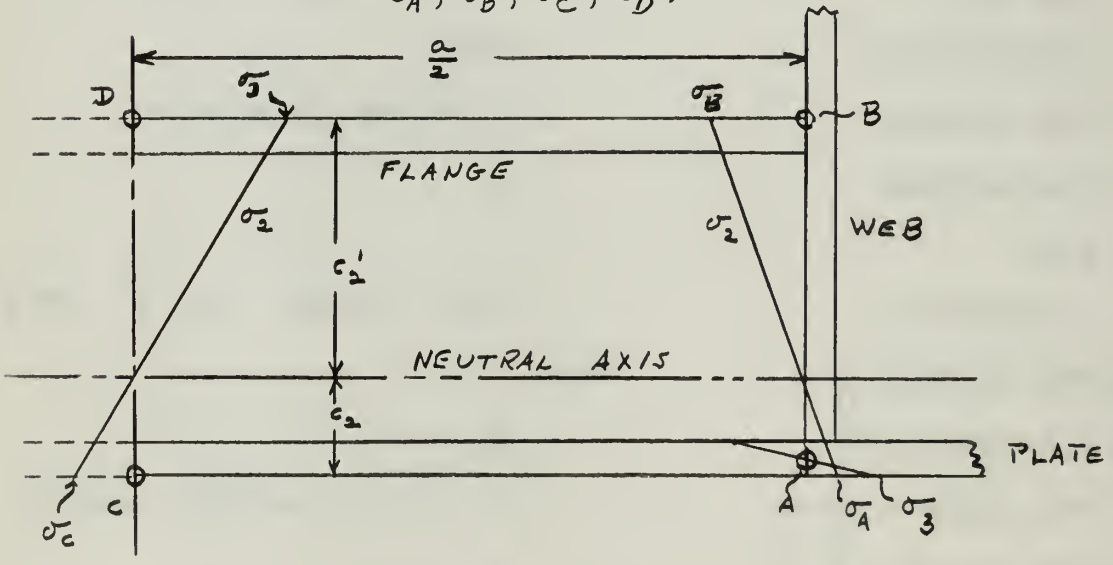


$$w = pb = H \times \frac{64b}{1728} = \frac{Hb}{27} \ \#/FT$$

$$M_2^+ = \frac{wa^2}{12} = \frac{Ha^2b}{324}, \quad M_2^- = \frac{wa^2}{8} = \frac{3}{2} \times \frac{wa^2}{12} = \frac{3}{2} M_2^+$$

FIGURE 7. Stresses due to Secondary Bending Moments

Stresses due to Secondary Bending Moments are referred to by location as: σ_A, σ_B, σ_C, σ_D.



PT	EQN	STRESS SCHEDULE
A	19	$\sigma_{yp}^+ \geq \sigma_1^+ + \sigma_A + \sigma_3$
	20	$\sigma_{yp}^- \geq \sigma_1^- - \sigma_A + \sigma_3$
B	21	$\sigma_{yp}^+ \geq \sigma_1^+ - \sigma_B$
	22	$\sigma_{yp}^- \geq \sigma_1^- + \sigma_B$
C	23	$\sigma_{yp}^+ \geq \sigma_1^+ - \sigma_C = \sigma_1^+ - 3/2\ \sigma_A$
	24	$\sigma_{yp}^- \geq \sigma_1^- + \sigma_C = \sigma_1^- + 3/2\ \sigma_A$
D	25	$\sigma_{yp}^+ \geq \sigma_1^+ + \sigma_D = \sigma_1^+ + 3/2\ \sigma_B$
	26	$\sigma_{yp}^- \geq \sigma_1^- - \sigma_D = \sigma_1^- - 3/2\ \sigma_B$

```
                71 |  71
        STO LOC+14,1                    THE SMALLER OF λ⁻ OR b
        TRA INDBB
INSBF   LXD NIX,1                       RESET INDEX 1
        REM CALCULATION OF SECONDARY BENDING MOMENTS
        LDQ INPUT+5                     a
        FMP INPUT+5                     a
        FDP CONST+19                    324
        FMP ASIDE+2                     b
        STO TEMP                        a²b/324
        LDQ TEMP                        a²b/324
INSBG   CLA LOC+1,1                     z
        TMI INSBH                       if z=-1 LEAVE LOOP
        LDQ LOC+15,1                    H5
        FMP TEMP                        a²b/324
        STO LOC+10,1                    M2 = H5 a²b/324
INDBC   TXI INSBG,1-32                  (-32)
INSBH   LXD NIX,1                       RESET INDEX 1
        REM REQUIRED SECTION MODULI
INSBI   CLA LOC+1,1                     z
        TMI INSBN                       if z=-1, LEAVE LOOP
        CLA INPUT+17                    σ_Y1^-
        FSB LOC+9,1                     σ1^-
        FDP CONST+26                    1.5
        STQ TEMP                        σ_A (24)
        CLA INPUT+16                    σ_Y1^+
        FSB LOC+8,1                     σ1^+
        FSB LOC+26,1                    σ3
        CAS TEMP                        COMPARE σ_A (17) WITH σ_A (24)
                76 |  76
```

Continuation of Discussion of Secondary Bending Stresses

DISREGARD:

COMPARING EQNS (19) AND (23): $\sigma_1^+ + \sigma_A > \sigma_1^+ - \frac{3}{2}\sigma_A$: EQN (23)

(22) (26) $\sigma_1^- + \sigma_B > \sigma_1^- - \frac{3}{2}\sigma_B$: EQN (26)

(21) (25) $\sigma_1^+ - \sigma_B < \sigma_1^+ + \frac{3}{2}\sigma_B$: EQN (21)

σ_A IS DEFINED BY INPUT + 19, ∴ EQN (19) COULD BE DISREGARDED. THE FOLLOWING STRESS SCHEDULE EQUATIONS ARE PERTINENT:

(19) $\sigma_A \leq \sigma_{YP}^+ - \sigma_1^+ - \sigma_3$ (22) $\sigma_B \leq \sigma_{YP}^- - \sigma_1^-$

(24) $\sigma_A \leq \frac{2}{3}(\sigma_{YP}^- - \sigma_1^-)$ (25) $\sigma_B \leq \frac{2}{3}(\sigma_{YP}^+ - \sigma_1^+)$

(20) $\sigma_A \geq \sigma_1^- + \sigma_3 - \sigma_{YP}^-$

Buship's criterion for span/radius of gyration is that $a/k \leq 50$ at the base line, $a/k \leq 50$ at the upper strength deck and that a/k varies linearity between the base line and the strength deck (ref. 6).

Moncriel's equation for a/k with a factor of safety of 1.0

$$\frac{a}{k} \leq \sqrt{\frac{9.6E(\sigma_{ULT} - 1.6\sigma_1^-)}{\sigma_1^-(\sigma_{ULT} - 0.88\sigma_1^-)}} = 16970.6\sqrt{\frac{\sigma_{ULT} - 1.6\sigma_1^-}{\sigma_1^-(\sigma_{ULT} - 0.88\sigma_1^-)}} \quad (27)$$

The above values of a/k are compared and the smaller or more conservative value is used in subsequent calculations.

CLA TEMP	σ_A (24)
NOP	
STO TEMP	THE SMALLER OF σ_A (19) OR σ_A (24) = σ_2
CLA LOC+10,1	M_2
FDP TEMP	σ_2
STQ LOC+12,1	I_2/c_2 (min) = M_2/σ_2
CLA INPUT+16	σ_{YP}^+
FSB LOC+8,1	σ_1^-
FDP CONST+26	1.5
STQ TEMP	σ_B (25)
CLA INPUT+17	σ_{YP}^-
FSB LOC+9,1	σ_1^-
CAS TEMP	COMPARE σ_B (22) WITH σ_B (25)
CLA TEMP	σ_B (?
NOP	
STO TEMP	THE SMALLER OF σ_B (22) OR σ_B (25) = σ_2'
CLA LOC+10,1	M_2
FDP TEMP	σ_2'
STQ LOC+13,1	I_2/c_2' (min) = M_2/σ_2'
REM SPAN/RADIUS OF GYRATION, BUSHIPS CRITERION	
CLA LOC+1,1	z
FDP INPUT	D
FMP CONST+25	20.0
FAD CONST+17	30.0
STO LOC+6,1	a/k (max) = $30 + 20\frac{z}{D}$
REM SPAN/RADIUS OF GYRATION, MONCRIEFF FACTOR OF SAFETY=1.0	
CLA LOC+9,1	σ_1^-
FSB INPUT+19	σ_2

```
                                                    73      73
      TMI INDBD                                      |       |     if σ1⁻ < σ2  SKIP
      LDQ LOC+9,1                                    |       |     σ1⁻
      FMP CONST+22                                   |       |     -1.6
      FAD INPUT+15                                   |       |     σULT
      TMI INDBD                                      |       |     if σULT < 1.6 σ1⁻ SKIP
      FDP LOC+9,1                                    |       |     σ1⁻
      STQ TEMP                                       |       |     1/σ1⁻ (σULT - 1.6 σ1⁻)
      LDQ LOC+9,1                                    |       |     σ1⁻
      FMP CONST+23                                   |       |     -0.88
      FAD INPUT+15                                   |       |     σULT
      STO TEMP+1                                     |       |     σULT - 0.88 σ1⁻
      CLA TEMP                                       |       |     1/σ1⁻ (σULT - 1.6 σ1⁻)
      FDP TEMP+1                                     |       |     σULT - 0.88 σ1⁻
      STQ TEMP                                       |       |   } (σULT - 1.6 σ1⁻) / (σ1⁻ (σULT - 0.88 σ1⁻))
      CLA TEMP                                       |       |
      TSX SQRT,4                                     |       |
      TRA INDBD                                      |       |     ERROR SKIP
      STO TEMP                                       |       |   } √( (σULT - 1.6 σ1⁻) / (σ1⁻ (σULT - 0.88 σ1⁻)) )   (27)
      LDQ TEMP                                       |       |
      FMP CONST+24                                   |       |     16970.6
      REM COMPARISON OF RADII OF GYRATION, THE LESSER VALUE IS USED
      CAS LOC+6,1                                    |       |     COMPARE a/k WITH a/k (MAX)
      CLA LOC+6,1                                    |       |     a/k (MAX)
      NOP                                            |       |
INSBM STO LOC+6,1                                    |       |     THE SMALLER VALUE OF a/k
INDBD TXI INSBI,1                                    |       (-32)
      REM PLATE PARAMETERS FOR SELECTION OF SCANTLINGS
INSBN LXD NIX,3                                      |             RESET INDICES 1 AND 2
```

```
INSBO CLA LOC+1,1      z
      TMI INSBQ        if z = -1, LEAVE LOOP
      LXD NIX,2        RESET INDEX 2
      CLA LOC+7,1      t
      FDP CONST+2      2
      STQ TEMP+6       ½t
      LDQ LOC+7,1      t
      FMP ASIDE+11     λ
      STO TEMP         λt
      LDQ TEMP         λt
      FMP LOC+7,1      t
      FDP CONST+5      12
      FMP LOC+7,1      t
      STO TEMP+1       λt³/12
      LDQ LOC+14,1     λ⁻
      FMP LOC+7,1      t
      STO TEMP+2       λ⁻t
      FDP CONST+5      12
      FMP LOC+14,1     λ⁻
      STO TEMP+7       (λ⁻)²t/12
      LDQ TEMP+7       (λ⁻)²t/12
      FMP LOC+14,1     λ⁻
      STO TEMP+7       (λ⁻)³t/12
      CLA TEMP+1       λt³/12
      FDP ASIDE+11     λ
      FMP LOC+14,1     λ⁻
      STO TEMP+3       λ⁻t³/12
      REM CONVERSION OF BEAM CHARACTERISTICS TO BEAM PLATE
```


84 ↓84

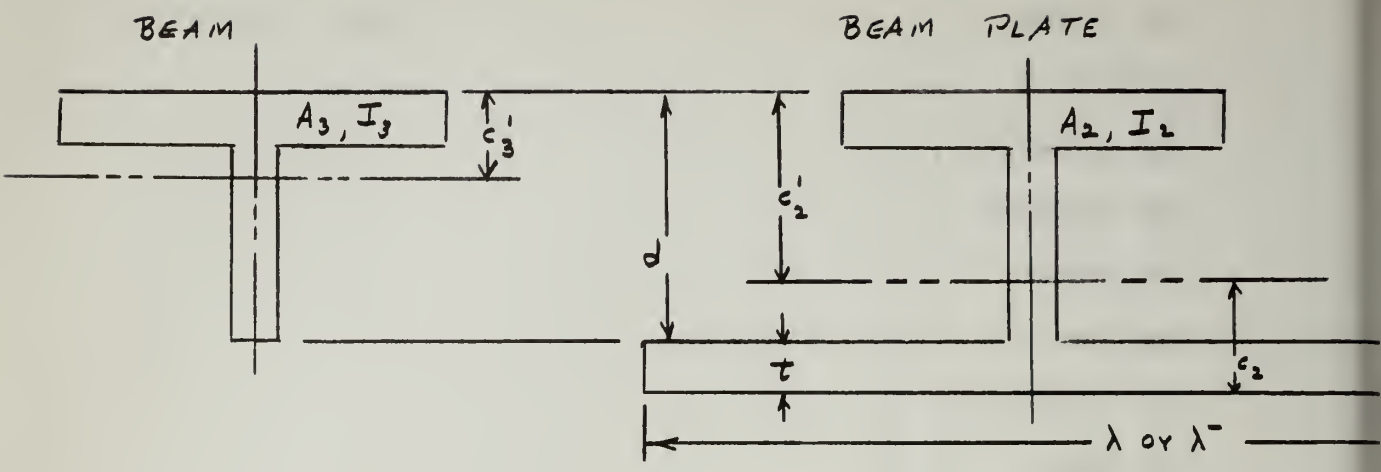


FIGURE 8

Beam, Beam Plate Geometry and Dimensions

$$A_2 = A_3 + \lambda t \quad (28)$$

$$c_2' = \frac{1}{A_2}\left[c_3' A_3 + \lambda t\left(d + \frac{t}{2}\right)\right]$$

$$= c_3' \frac{(A_2 - \lambda t)}{A_2} + \frac{\lambda t}{A_2}\left(d + \frac{t}{2}\right)$$

$$= c_3' - \frac{\lambda t}{A_2} c_3' + \frac{\lambda t}{A_2}\left(d + \frac{t}{2}\right)$$

$$c_2' = c_3' + \frac{\lambda t}{A_2}\left(d + t/2 - c_3'\right) \quad (30)$$

$$c_2 = d + t - c_2' \quad (32)$$

$$I_2 = I_3 + A_3\left(c_2' - c_3'\right)^2 + \frac{\lambda t^3}{12} + \lambda t\left(c_2 - \frac{t}{2}\right)^2 \quad (34)$$

$$I_{2YY} = I_{3YY} + \frac{b^3 t}{12} \quad (36)$$

$$A_2^- = A_3 + \lambda^- t \quad (29)$$

$$c_2'^- = \frac{1}{A_2^-}\left[c_3' A_3 + \lambda^- t\left(d + \frac{t}{2}\right)\right]$$

$$c_2'^- = c_3' + \frac{\lambda^- t}{A_2}\left(d + t/2 - c_3'\right) \quad (31)$$

$$c_2^- = d + t - c_2'^- \quad (33)$$

$$I_2^- = I_3 + A_3\left(c_2' - c_3'\right)^2 + \frac{\lambda^- t^3}{12} + \lambda^- t\left(c_2^- - \frac{t}{2}\right)^2 \quad (35)$$

$$I_{2YY}^- = I_{3YY} + \frac{(\lambda^-)^3 t}{12} \quad (37)$$

$$K^2 = \frac{I_2^-}{A_2^-} \quad (38)$$

```
      REM CHARACTERISTICS, AREA, LOCATION NA, MOMENT OF INERTIA
      REM CALCULATION OF EFFECTIVE AREAS
INSBP CLA SCANT+3,2<                  A3
      TMI INDCA+10-                   if THERE IS NO BEAM, SKIP
      FAD TEMP                        λt
      STO TEMP+4                      A2 = A3 + λt    (28)
      CLA SCANT+3,2                   A3
      FAD TEMP+2                      λ⁻t
      STO TEMP+5                      A2⁻ = A3 + λ⁻t  (29)
      REM CALCULATION OF EFFECTIVE I (YY)
      LDQ ASIDE+4                     b³/12
      FMP LOC+7,1                     t
      FAD SCANT+6,2                   I3YY
      STO TEMP+8                      I2YY = I3YY + b³t/12   (36)
      CLA TEMP+7                      (λ⁻)³t /12
      FAD SCANT+6,2                   I3YY
      STO TEMP+9                      I2YY⁻ = I3YY + (λ⁻)³t /12   (37)
      REM CALCULATION OF NEUTRAL AXES
      CLA SCANT+9,2                   d
      FSB SCANT+4,2                   c3'
      FAD TEMP+6                      ½t
      STO TEMP+20                     d - c3' + t/2
      FDP TEMP+4                      A2
      FMP TEMP                        λt
      FAD SCANT+4,2                   c3'
      STO TEMP+10                     c2' = (λt/A2)(d - c3' + t/2) + c3'   (30)
      CLA TEMP+20                     d - c3' + t/2
      FDP TEMP+5                      A2⁻
```


82 ↓ 82

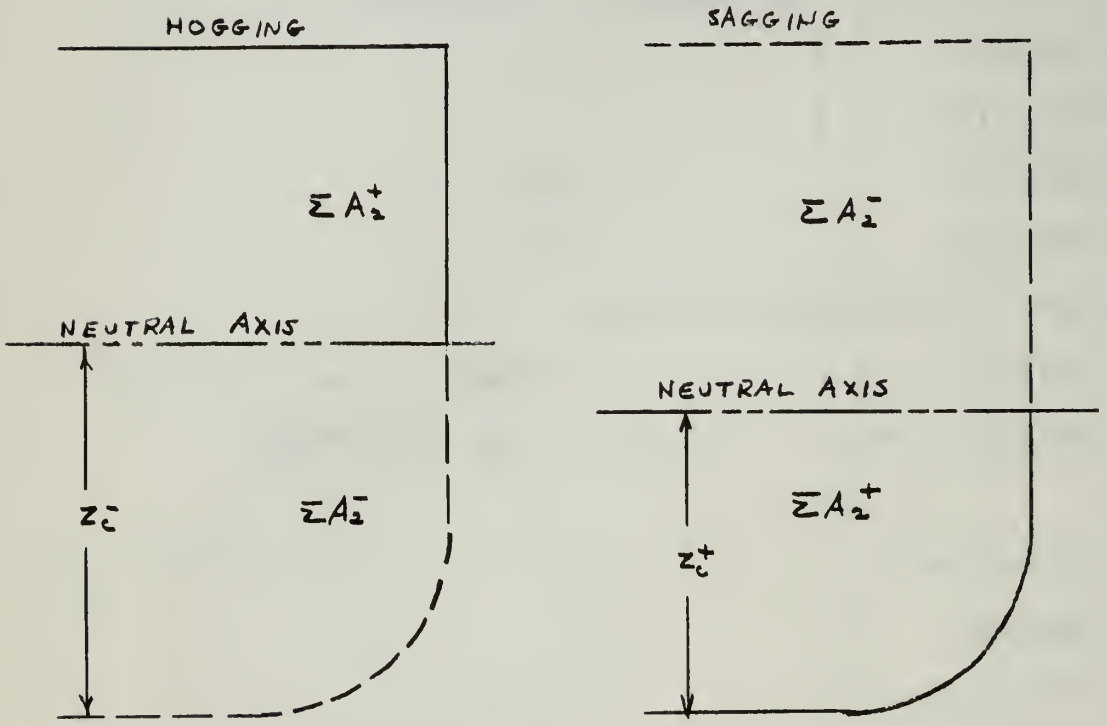
FMP TEMP+2	$\lambda^- t$
FAD SCANT+4,2	c_3'
STO TEMP+11	$c_2'^- = \frac{\lambda^- t}{A_2^-}(d - c_3' + \frac{t}{2}) + c_3'$ (31)
REM CALCULATION OF EFFECTIVE MOMENTS OF INERTIA	
FSB SCANT+4,2	c_3'
STO TEMP+15	$c_2'^- - c_3'$
LDQ TEMP+15	$c_2'^- - c_3'$
FMP TEMP+15	$c_2'^- - c_3'$
STO TEMP+15	$(c_2'^- - c_3')^2$
LDQ TEMP+15	$(c_2'^- - c_3')^2$
FMP SCANT+3,2	A_3
FAD SCANT+5,2	I_3
STO TEMP+15	$I_3 + A_3 (c_2'^- - c_3')^2$
CLA TEMP+10	c_2'
FSB SCANT+4,2	c_3'
STO TEMP+14	$c_2' - c_3'$
LDQ TEMP+14	$c_2' - c_3'$
FMP TEMP+14	$c_2' - c_3'$
STO TEMP+14	$(c_2' - c_3')^2$
LDQ TEMP+14	$(c_2' - c_3')^2$
FMP SCANT+3,2	A_3
FAD SCANT+5,2	I_3
STO TEMP+14	$I_3 + A_3 (c_2' - c_3')^2$
CLA SCANT+9,2	d
FAD LOC+7,1	t
STO TEMP+16	$d + t$
FSB TEMP+10	c_2'
STO TEMP+12	$c_2 = d + t - c_2'$ (32)

CLA TEMP+16	$d+t$
FSB TEMP+11	$c_2'^-$
STO TEMP+13	$c_2^- = d' + t - c_2'^-$ (33)
FSB TEMP+6	$t/2$
STO TEMP+16	$c_2^- - t/2$
LDQ TEMP+16	$c_2^- - t/2$
FMP TEMP+16	$c_2^- - t/2$
STO TEMP+16	$(c_2^- - t/2)^2$
LDQ TEMP+16	$(c_2^- - t/2)^2$
FMP TEMP+2	$\lambda^- t$
FAD TEMP+3	$\lambda^- t^3/12$
FAD TEMP+15	$I_3 + A_3 (c_2'^- - c_3')^2$
STO TEMP+15	$I_2^- = I_3 + A_3 (c_2'^- - c_3')^2 + \frac{\lambda^- t^3}{12} + \lambda^- t (c_2^- - \frac{t}{2})^2$ (35)
CLA TEMP+12	c_2
FSB TEMP+6	$t/2$
STO TEMP+16	$c_2 - t/2$
LDQ TEMP+16	$c_2 - t/2$
FMP TEMP+16	$c_2 - t/2$
STO TEMP+16	$(c_2 - t/2)^2$
LDQ TEMP+16	$(c_2 - t/2)^2$
FMP TEMP	λt
FAD TEMP+1	$\lambda t^3/12$
FAD TEMP+14	$I_3 + A_3 (c_3' - c_3')^2$
STO TEMP+14	$I_2 = I_3 + A_3 (c_3' - c_3')^2 + \frac{\lambda t^3}{12} + \lambda t (c_2 - t/2)^2$ (34)
REM CALCULATION OF RADIUS OF GYRATION	
CLA TEMP+15	I_2^-
FDP TEMP+5	A_2^-
STQ TEMP+16	$k^2 = I_2^- / A_2^-$ (38)

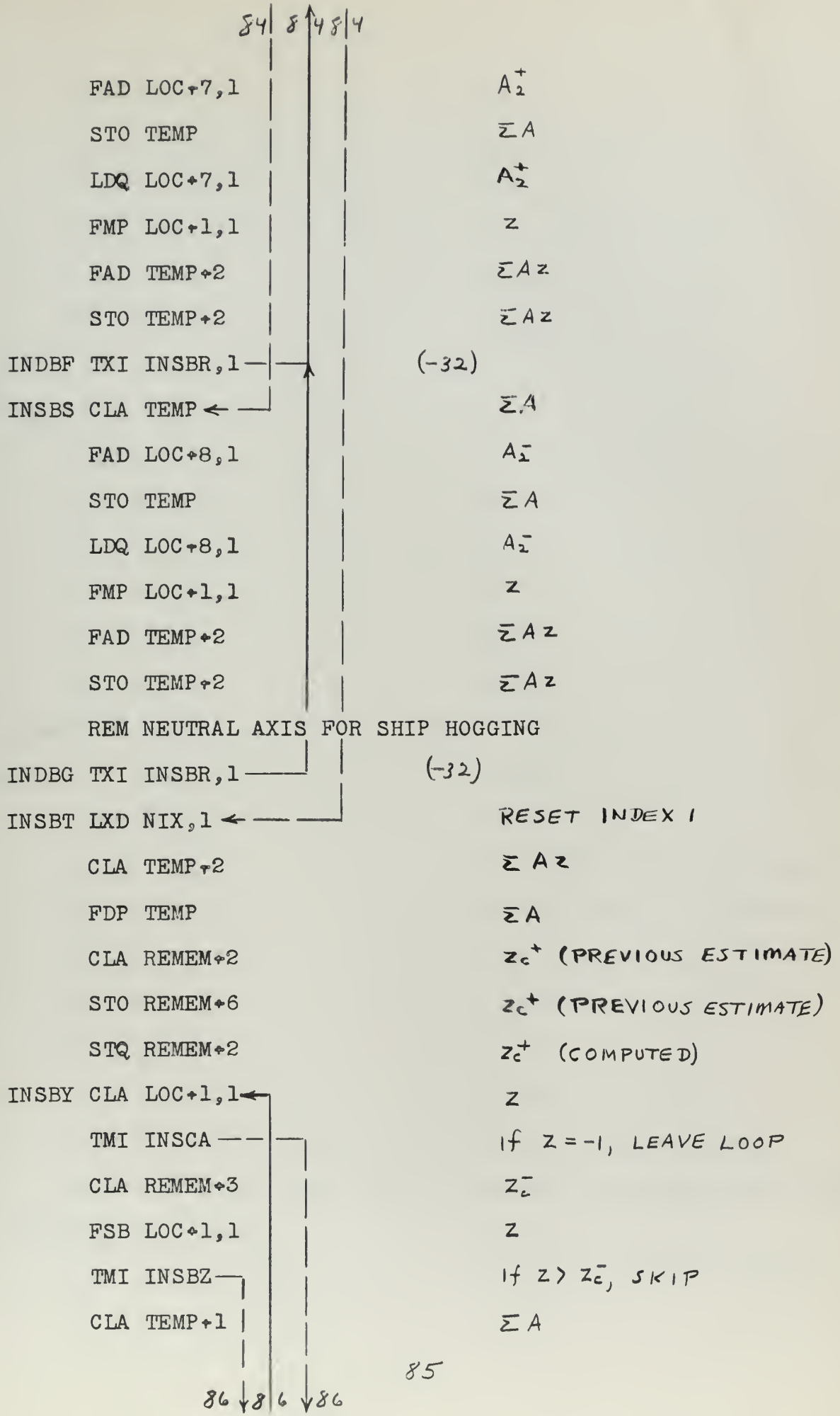
```
                                                    79   79
      CLA TEMP+16                                        K^2
      TSX SQRT,4
      HTR                                                ERROR STOP
      STO TEMP+16                                        K
      REM CALCULATION OF SPAN/RADIUS OF GYRATION
      CLA INPUT+5                                        a
      FDP TEMP+16                                        K
      STQ TEMP+16                                        a/K
      CLA TEMP+16                                        a/K
      REM TEST OF SELECTED SCANTLING
      CAS LOC+6,1                                        COMPARE a/K WITH a/K (MAX)
INDCA TXI INSBP,2                                  (-10) if a/K > a/K (MAX)
      NOP
      CLA TEMP+14                                        I2
      FDP TEMP+12                                        c2
      CLA LOC+12,1                                       I2/c2 (MIN)
      TLQ INDCA                                          IF I2/c2 < I2/c2 (MIN)
      CLA TEMP+14                                        I2
      FDP TEMP+10                                        c2'
      CLA LOC+13,1                                       I2/c2' (MIN)
      TLQ INDCA                                          if I2/c2' < I2/c1 (MIN)
      REM STORING DESCRIPTION AND PROPERTIES OF SELECTED SCANTLING
      CLA SCANT,2                                        BEAM DESIGNATION
      STO LOC+3,1                                        "      "
      CLA SCANT+1,2                                      "      "
      STO LOC+4,1                                        "      "
      CLA SCANT+2,2                                      "      "
      STO LOC+5,1                                        "      "
```

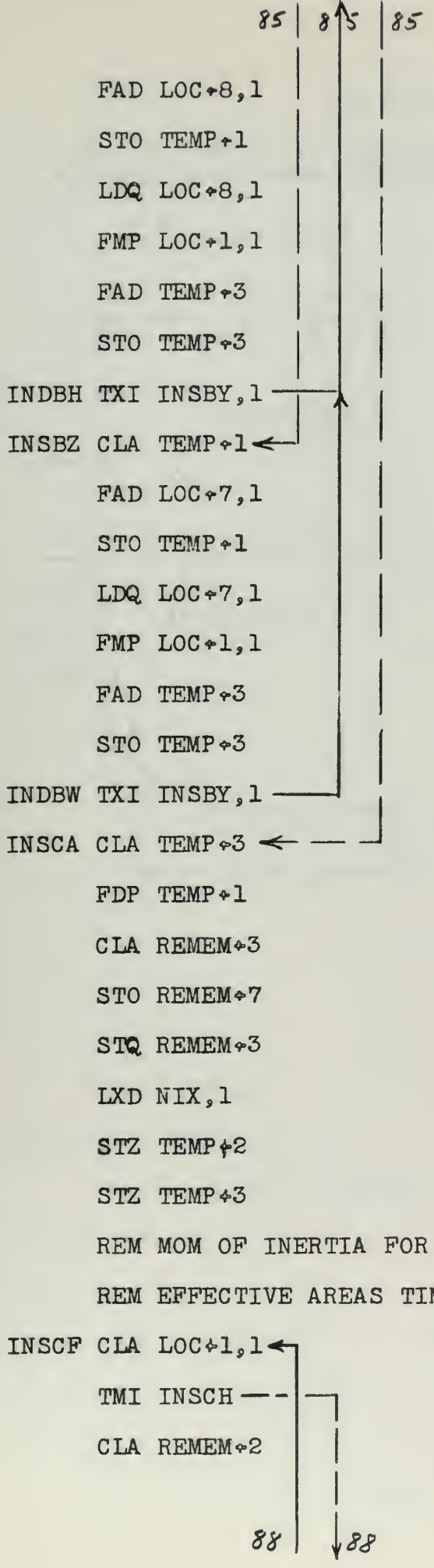
FIGURE 9

Effective Areas for determining Locations of Neutral Axes



```
                77 ↑  | 77
                   |  |
        LDQ LOC+7,1|  |          t
        FMP ASIDE+2|  |          b
        FAD SCANT+3,2  |          A3
        STO LOC+7,1|  |          A2+ = A3 + bt
        CLA TEMP+5 |  |          A2-
        STO LOC+8,1|  |          A1-
        CLA TEMP+14|  |          I2
        STO LOC+9,1|  |          I2-
        CLA TEMP+15|  |          I1-
        STO LOC+10,1   |          I1-
        CLA TEMP+8 |  |          I2yy
        STO LOC+11,1   |          I1yy
        CLA TEMP+9 |  |          I2-yy
        STO LOC+12,1   |          I1-yy
INDBE   TXI INSBO,1 ---|    (-32)
        REM LOCATION OF NEUTRAL AXES, ACCURACY TO HALF SCANT SPACE
        REM NEUTRAL AXIS FOR SHIP SAGGING
INSBQ   LXD NIX,3 <----|          RESET INDICES 1 AND 2
        STZ TEMP   |  |          0.0
        STZ TEMP+1 |  |          0.0
        STZ TEMP+2 |  |          0.0
        STZ TEMP+3 |  |          0.0
INSBR   CLA LOC+1,1 <--|          z
        TMI INSBT ---  |          if z = -1, LEAVE LOOP
        CLA REMEM+2|   |          zc+
        FSB LOC+1,1|   |          z
        TMI INSBS --|  |          if z > zc+, SKIP
        CLA TEMP   |   |          Σ A
                   |   |
                   |   |    84
                   |   |
                85 ↓ 85 ↓ 85
```

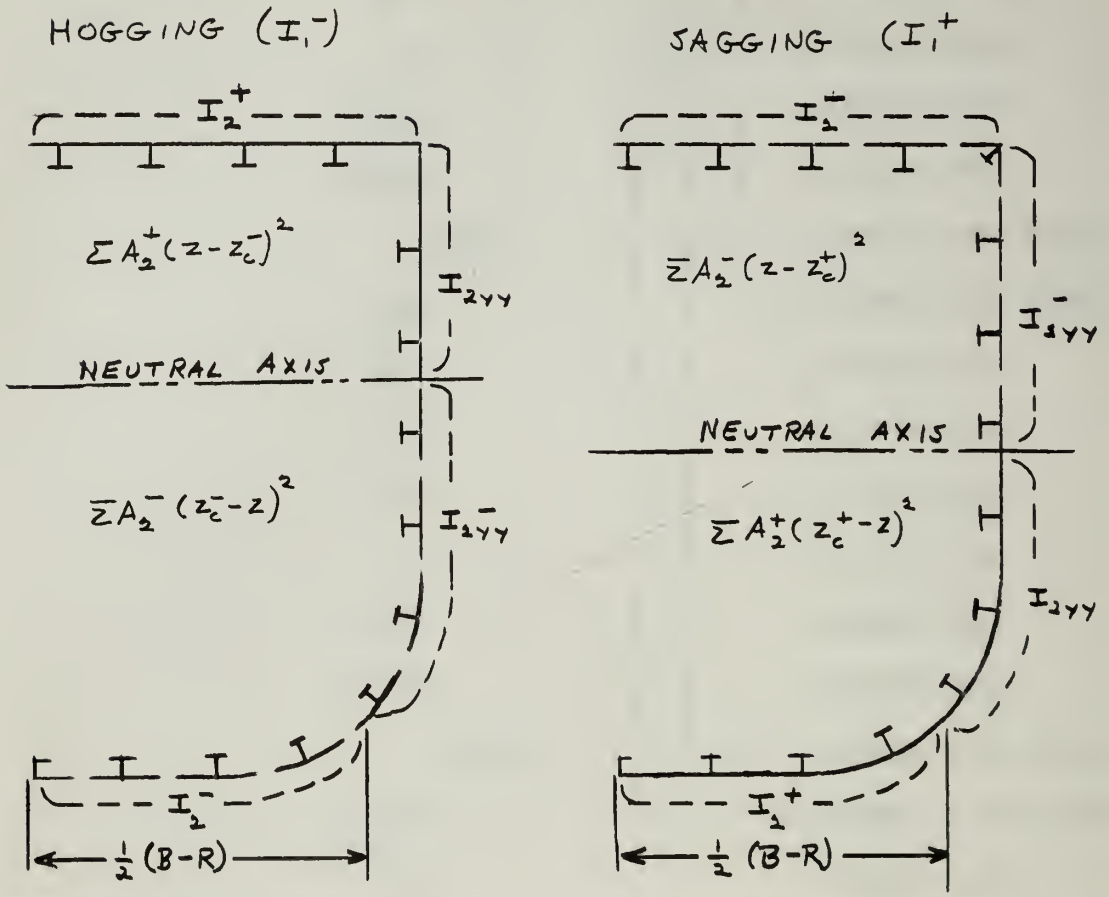

84 8 48 4
FAD LOC+7,1 A_2^+
STO TEMP ΣA
LDQ LOC+7,1 A_2^+
FMP LOC+1,1 z
FAD TEMP+2 $\Sigma A z$
STO TEMP+2 $\Sigma A z$
INDBF TXI INSBR,1 (-32)
INSBS CLA TEMP ΣA
FAD LOC+8,1 A_2^-
STO TEMP ΣA
LDQ LOC+8,1 A_2^-
FMP LOC+1,1 z
FAD TEMP+2 $\Sigma A z$
STO TEMP+2 $\Sigma A z$
REM NEUTRAL AXIS FOR SHIP HOGGING
INDBG TXI INSBR,1 (-32)
INSBT LXD NIX,1 RESET INDEX 1
CLA TEMP+2 $\Sigma A z$
FDP TEMP ΣA
CLA REMEM+2 z_c^+ (PREVIOUS ESTIMATE)
STO REMEM+6 z_c^+ (PREVIOUS ESTIMATE)
STQ REMEM+2 z_c^+ (COMPUTED)
INSBY CLA LOC+1,1 z
TMI INSCA if z = -1, LEAVE LOOP
CLA REMEM+3 z_c^-
FSB LOC+1,1 z
TMI INSBZ if z > z_c^-, SKIP
CLA TEMP+1 ΣA
86 8 6 86

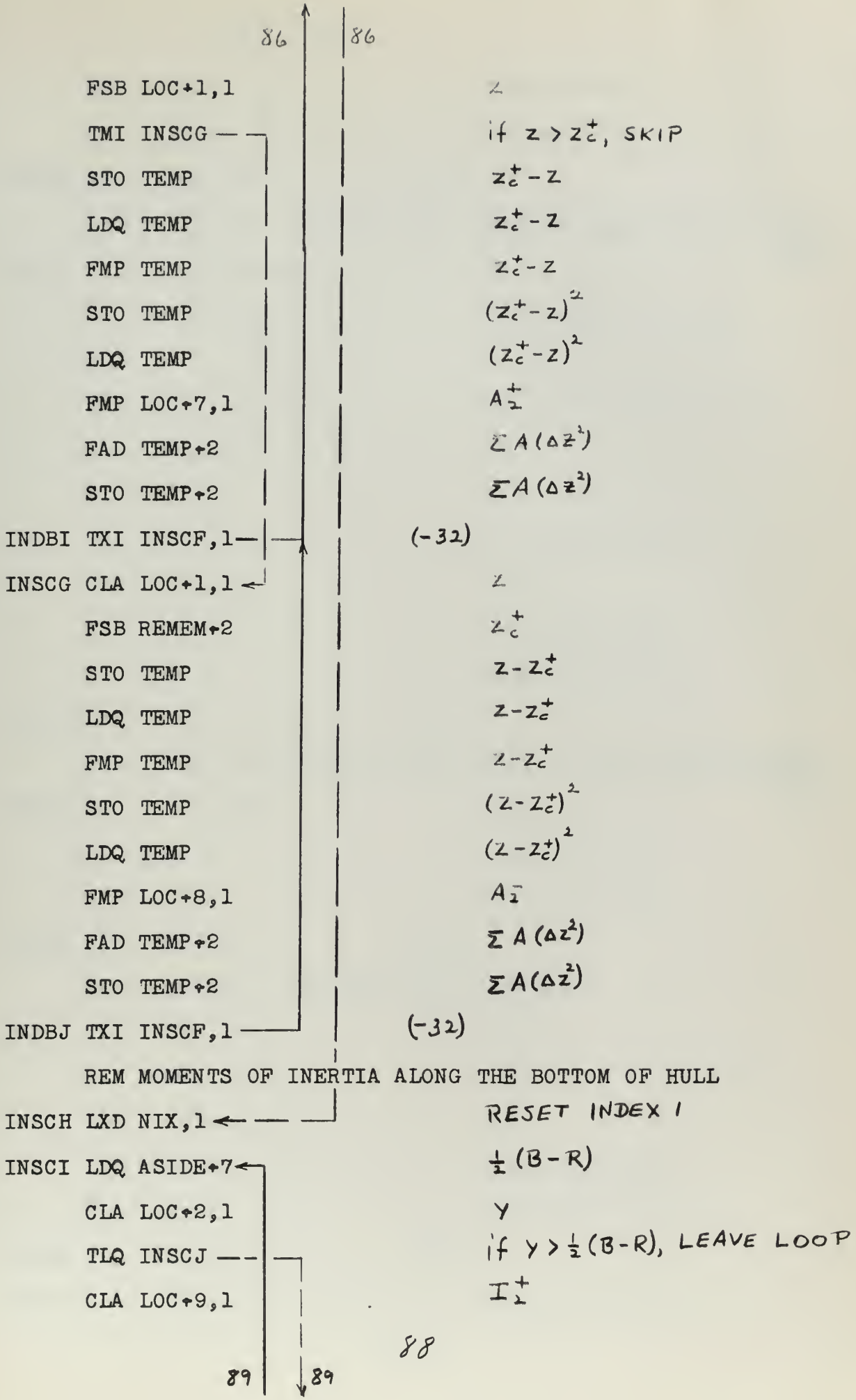



```
        FAD LOC+8,1          A2-
        STO TEMP+1           ΣA
        LDQ LOC+8,1          A2-
        FMP LOC+1,1          z
        FAD TEMP+3           ΣAz
        STO TEMP+3           ΣAz
INDBH   TXI INSBY,1  (-32)
INSBZ   CLA TEMP+1           ΣA
        FAD LOC+7,1          A2+
        STO TEMP+1           ΣA
        LDQ LOC+7,1          A2+
        FMP LOC+1,1          z
        FAD TEMP+3           ΣAz
        STO TEMP+3           ΣAz
INDBW   TXI INSBY,1  (-32)
INSCA   CLA TEMP+3           ΣAz
        FDP TEMP+1           ΣA
        CLA REMEM+3          zc-  (PREVIOUS ESTIMATE)
        STO REMEM+7          zc-  (PREVIOUS ESTIMATE)
        STQ REMEM+3          zc-  (COMPUTED)
        LXD NIX,1            RESET INDEX 1
        STZ TEMP+2           0.0
        STZ TEMP+3           0.0
        REM MOM OF INERTIA FOR POSITIVE SHIP BENDING MOMENT
        REM EFFECTIVE AREAS TIMES DISTANCES TO NEUTRAL AXIS SQUARED
INSCF   CLA LOC+1,1          z
        TMI INSCH            if z=-1, LEAVE LOOP
        CLA REMEM+2          zc+
```

FIGURE 10

Effective areas and moments of inertia for determining total effective moments of inertia




86
86
FSB LOC+1,1
TMI INSCG
STO TEMP
LDQ TEMP
FMP TEMP
STO TEMP
LDQ TEMP
FMP LOC+7,1
FAD TEMP+2
STO TEMP+2
INDBI TXI INSCF,1
INSCG CLA LOC+1,1
FSB REMEM+2
STO TEMP
LDQ TEMP
FMP TEMP
STO TEMP
LDQ TEMP
FMP LOC+8,1
FAD TEMP+2
STO TEMP+2
INDBJ TXI INSCF,1
REM MOMENTS OF INERTIA ALONG THE BOTTOM OF HULL
INSCH LXD NIX,1
INSCI LDQ ASIDE+7
CLA LOC+2,1
TLQ INSCJ
CLA LOC+9,1
89
89
88
(-32)
(-32)
z
if z > z_c^+, SKIP
z_c^+ - z
z_c^+ - z
z_c^+ - z
(z_c^+ - z)^2
(z_c^+ - z)^2
A_i^+
Σ A (Δz^2)
Σ A (Δz^2)
z
z_c^+
z - z_c^+
z - z_c^+
z - z_c^+
(z - z_c^+)^2
(z - z_c^+)^2
A_i^-
Σ A (Δz^2)
Σ A (Δz^2)
RESET INDEX 1
½ (B - R)
Y
if Y > ½ (B-R), LEAVE LOOP
I_i^+

```
                                                88 | 88
        FAD TEMP+2                                 |          Σ A(Δz²)+Σ I₂
        STO TEMP+2                                 |          Σ A(Δz²)+Σ I₂
INDBK   TXI INSCI,1                                |  (-32)
        REM MOMENTS OF INERTIA ALONG SIDE OF HULL BELOW NEUTRAL AXIS
INSCJ   CLA LOC+1,1                                |          z
        CAS INPUT                                  |          COMPARE A WITH D
        NOP                                        |
        TRA INSCL                                  |          IF z = D, LEAVE LOOP
        CLA REMEM+2                                |          z_c^+
        FSB LOC+1,1                                |          z
        TMI INSCK                                  |          IF z > z_c^+, SKIP
        CLA LOC+11,1                               |          I_2yy^+
        FAD TEMP+2                                 |          Σ A(Δz²) + Σ I₂
        STO TEMP+2                                 |          Σ A(Δz²) + Σ I₂
INDBL   TXI INSCJ,1                                |  (-32)
        REM MOMENTS OF INERTIA ALONG SIDE OF HULL ABOVE NEUTRAL AXIS
INSCK   CLA LOC+12,1                               |          I_2yy^-
        FAD TEMP+2                                 |          Σ A(Δz²) + Σ I₂
        STO TEMP+2                                 |          Σ A(Δz²) + Σ I₂
INDBM   TXI INSCJ,1                                |  (-32)
        REM MOMENTS OF INERTIA ALONG THE DECK
INSCL   CLA LOC+1,1                                |          z
        TMI INSCM                                  |          if z=-1, LEAVE LOOP
        CLA LOC+10,1                               |          I_2^-
        FAD TEMP+2                                 |          Σ A(Δz²) + Σ I₂
        STO TEMP+2                                 |          Σ A(Δz²) + Σ I₂
INDBN   TXI INSCL,1                                |  (-32)
INSCM   LXD NIX,1                                  |          RESET INDEX 1
```

```
      REM MOMENT OF INERTIA FOR NEGATIVE BENDING MOMENT
      REM EFFECTIVE AREAS TIMES DISTANCES TO NEUTRAL AXIS SQUARED
INSCN CLA LOC+1,1          z
      TMI INSCP            if z=-1, LEAVE LOOP
      CLA REMEM+3          z_c^-
      FSB LOC+1,1          z
      TMI INSCO            if z>z_c^-, SKIP
      STO TEMP+1           z_c^- - z
      LDQ TEMP+1           z_c^- - z
      FMP TEMP+1           z_c^- - z
      STO TEMP+1           (z_c^- - z)^2
      LDQ TEMP+1           (z_c^- - z)^2
      FMP LOC+8,1          A_z^-
      FAD TEMP+3           Σ^- A(Δz^2)
      STO TEMP+3           Σ A(Δz^2)
INDBO TXI INSCN,1-1        (-32)
INSCO CLA LOC+1,1          z
      FSB REMEM+3          z_c^-
      STO TEMP+1           z - z_c^-
      LDQ TEMP+1           z - z_c^-
      FMP TEMP+1           z - z_c^-
      STO TEMP+1           (z - z_c^-)^2
      LDQ TEMP+1           (z - z_c^-)^2
      FMP LOC+7,1          A_z^+
      FAD TEMP+3           Σ A(Δz^2)
      STO TEMP+3           Σ A(Δz^2)
INDBP TXI INSCN,1          (-32)
      REM MOMENTS OF INERTIA ALONG THE BOTTOM OF HULL
```

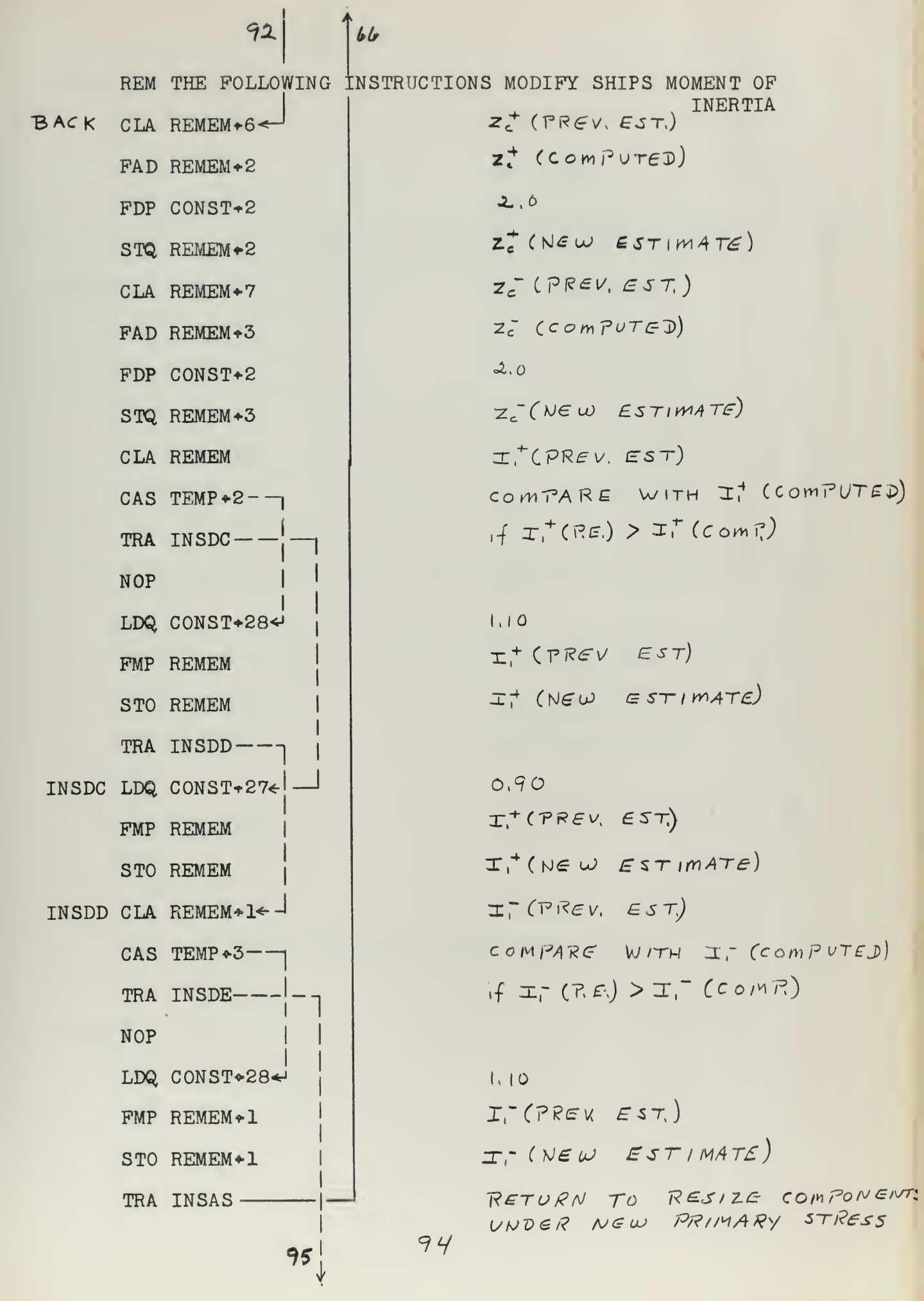
```
                                                    90
INSCP LXD NIX,1←                                    RESET INDEX 1
INSCQ LDQ ASIDE+7←                                  ½(B-K)
      CLA LOC+2,1                                   Y
      TLQ INSCR                                     if Y>½(B-K), LEAVE LOOP
      CLA LOC+10,1                                  I₂⁻
      FAD TEMP+3                                    Σ A(Δz²) + Σ I₂
      STO TEMP+3                                    Σ A(Δz²) + Σ I₂
INDBQ TXI INSCQ,1                   (-32)
      REM MOMENTS OF INERTIA ALONG SIDE OF HULL BELOW NEUTRAL AXIS
INSCR CLA LOC+1,1←                                  z
      CAS INPUT                                     D
      NOP
      TRA INSCT                                     if z=D, LEAVE LOOP
      CLA REMEM+3                                   z̄
      FSB LOC+1,1                                   z
      TMI INSCS                                     if z>z̄, SKIP
      CLA LOC+12,1                                  I⁻₂yy
      FAD TEMP+3                                    Σ A(Δz²) + Σ I₂
      STO TEMP+3                                    Σ A(Δz²) + Σ I₂
INDBR TXI INSCR,1                   (-32)
      REM MOMENTS OF INERTIA ALONG SIDE OF HULL ABOVE NEUTRAL AXIS
INSCS CLA LOC+11,1←                                 I⁺₂yy
      FAD TEMP+3                                    Σ A(Δz²) + Σ I₂
      STO TEMP+3                                    Σ A(Δz²) + Σ I₂
INDBS TXI INSCR,1                   (-32)
      REM MOMENTS OF INERTIA ALONG THE DECK
INSCT CLA LOC+1,1←                                  z
      TMI INSCU                                     if z=-1, LEAVE LOOP
                                                    91
                    92          92
```

```
                                                    91 | 91
      CLA LOC+9,1                                     |      I_2^+
      FAD TEMP+3                                      |      Σ A(Δz²) + Σ I_2
      STO TEMP+3                                      |      Σ A(Δz²) + Σ I_2
INDBT TXI INSCT,1 ------------------------------------|  (-32)
INSCU LXD NIX,1 <-------------------------------------|      RESET INDEX 1
      TSX M,4                                         |      PRINT OUT I_1^+ AND I_1^- FOR
      PZE REMEM,0,REMEM+1                             |      CHECK OF INTERMEDIATE
                                                      |      ESTIMATES OF MOM. OF INERTIA
      REM ACCURACY TEST FOR MOMENTS OF INERTIA        |
      CLA TEMP+3                                      |      I_1^- (COMPUTED)
      FSB REMEM+1                                     |      I_1^- (PREVIOUS ESTIMATE)
      FDP REMEM+1                                     |      I_1^- (PREVIOUS ESTIMATE)
      STQ TEMP                                        |      ΔI_1^- = (I_1^-(COMP) - I_1^-(P.E.)) / I_1^-(P.E.)
      CLA TEMP                                        |      ΔI_1^-
      SSP                                             |
      CAS INPUT+11 ---------------------------------- |      COMPARE ΔI_1^- WITH ΔI_1 (MAX)
      NOP                                             |
      TRA BACK ------------------------------------ | |      if ΔI_1^- ≥ ΔI_1^- (MAX)
      CLA TEMP+2 <---------------------------------- |      I_1^+ (COMPUTED)
      FSB REMEM                                       |      I_1^+ (PREVIOUS ESTIMATE)
      FDP REMEM                                       |      I_1^+ (PREVIOUS ESTIMATE)
      STQ TEMP                                        |      ΔI_1^+ = (I_1^+(COMP) - I_1^+(P.E.)) / I_1^+(P.E.)
      CLA TEMP                                        |      ΔI_1^+
      SSP                                             |
      CAS INPUT+11 ---------------------------------- |      COMPARE ΔI_1^+ WITH ΔI_1 (MAX)
      NOP                                             |
      TRA BACK ------------------------------------ | |      if ΔI_1^+ ≥ ΔI_1 (MAX)
      TRA INSCV ----------------------------------- | |      if ΔI_1^+ AND ΔI_1^- ARE < ΔI_1(MAX)
      REM ACCURACY CRITERIA FOR SHIP MOMENTS OF INERTIA HAS
                                                          FAILED,
                                                    92
                                                 94 | 95
```

Accuracy criterion for hull moment of inertia is given as a decimal fraction by INPUT+11 (ΔI). If this criterion is not met, the moments of inertia are altered by amounts given by CONST+27 and CONST+28 which are in this case 10% of the originally assumed moments of inertia.

The accuracy requirement for location of neutral axis is specified as one half the distance between longitudinals. If this criterion is not met, a mean between assumed and computed values of locations of neutral axes are used as the new assumptions.

The above has been found to be necessary in order to force the problem to a solution.


92
66
REM THE FOLLOWING INSTRUCTIONS MODIFY SHIPS MOMENT OF INERTIA
BACK CLA REMEM+6
FAD REMEM+2
FDP CONST+2
STQ REMEM+2
CLA REMEM+7
FAD REMEM+3
FDP CONST+2
STQ REMEM+3
CLA REMEM
CAS TEMP+2
TRA INSDC
NOP
LDQ CONST+28
FMP REMEM
STO REMEM
TRA INSDD
INSDC LDQ CONST+27
FMP REMEM
STO REMEM
INSDD CLA REMEM+1
CAS TEMP+3
TRA INSDE
NOP
LDQ CONST+28
FMP REMEM+1
STO REMEM+1
TRA INSAS
z_c^+ (PREV. EST.)
z_c^+ (COMPUTED)
2.0
z_c^+ (NEW ESTIMATE)
z_c^- (PREV. EST.)
z_c^- (COMPUTED)
2.0
z_c^- (NEW ESTIMATE)
I_1^+ (PREV. EST)
COMPARE WITH I_1^+ (COMPUTED)
if I_1^+ (P.E.) > I_1^+ (COMP.)
1.10
I_1^+ (PREV EST)
I_1^+ (NEW ESTIMATE)
0.90
I_1^+ (PREV. EST.)
I_1^+ (NEW ESTIMATE)
I_1^- (PREV. EST.)
COMPARE WITH I_1^- (COMPUTED)
if I_1^- (P.E.) > I_1^- (COMP.)
1.10
I_1^- (PREV EST.)
I_1^- (NEW ESTIMATE)
RETURN TO RESIZE COMPONENTS UNDER NEW PRIMARY STRESS
95
94

94 6 6 92

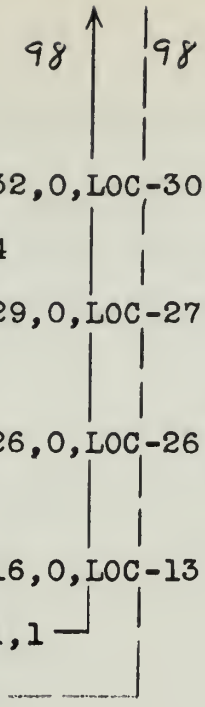
```
INSDE LDQ CONST+27      0.90
      FMP REMEM+1       I1- (PREV. EST.)
      STO REMEM+1       I1- (NEW ESTIMATE)
      TRA INSAS         RETURN TO RESIZE COMPONENTS
                        UNDER NEW PRIMARY STRESS
      REM ACCURACY TESTS FOR LOCATIONS OF NEUTRAL AXES
INSCV CLA TEMP+3        I1- (COMPUTED)
      STO REMEM+1       I1-
      CLA TEMP+2        I1+ (COMPUTED)
      STO REMEM         I1+
      CLA REMEM+6       Zc+ (PREV. EST.)
      FSB REMEM+2       Zc+ (COMPUTED)
      SSP
      CAS ASIDE+8       COMPARE ΔZc+ WITH b/2
      NOP
      TRA INSAS         IF ΔZc+ > b/2 RETURN
      CLA REMEM+7       Zc- (PREV. EST.)
      FSB REMEM+3       Zc- (COMPUTED)
      SSP
      CAS ASIDE+8       COMPARE ΔZc- WITH b/2
      NOP
      TRA INSAS         IF ΔZc- > b/2 RETURN
      REM CALCULATION OF TOTAL CROSS SECTION AREA
      STZ TEMP          0.0
INSBX CLA LOC+1,1       Z
      TMI INSCW         IF Z = -1, LEAVE LOOP
      CLA LOC+7,1       A2+
      FAD TEMP          ΣA
      STO TEMP          ΣA
```


96 96

```
                95 ↑  |95
INDBU TXI INSBX,1 ←   |        (-32)
      REM STORE AREA, NR SCANTLINGS AND FRAME SPACING
INSCW CLA TEMP ←  -   -                    A,+
      STO REMEM+12                         A,+
      CLA ASIDE                            n
      STO REMEM+13                         n
      CLA INPUT+5                          a
      STO REMEM+14                         a
      TSX L,4                              PRINT OUT A,+, n, a
      PZE REMEM+12,0,REMEM+14
      CLA TEMP+18                          CONTROL LOCATION
      TMI INSCZ+9 ---                      if CONTROL LOCATION HAS -1.0
      REM COMPARE AREA WITH MINIMUM AREA THUS FAR OBTAINED
                                             AND STORE TH
      REM LESSER VALUE OF THE TWO AREAS AND ITS NR. SCANT.
                                             AND FR. SPAC
      CLA REMEM+12                         A,+
      CAS REMEM+5                          COMPARE A,+ WITH A,+(MIN)
      NOP
      TRA INSDB ---                        if A,+ ≥ A,+ (MIN)
      CLA REMEM+12                         A,+
      STO REMEM+5                          A,+ = A,+ (min)
      CLA REMEM+13                         a
      STO REMEM+8                          a (for min A)
      CLA REMEM+14                         n
      STO REMEM+9                          n (for min A)
      REM RESET FOR NEXT NUMBER OF LONGITUDINALS
INSDB LXD NIX,3 ←                          RESET INDICES 1 AND 2
      CLA ASIDE                            n
                |98    96
                ↓
```

```
      FAD INPUT+9                    Δn
      STO ASIDE                      n
      CAS INPUT+10                   COMPARE n WITH nf
      TRA INSCY                      if n > nf
      NOP
INSCX LDQ ASIDE+1                    b0
      FMP INPUT+8                    n0
      FDP ASIDE                      n
      STQ ASIDE+2                    b = b0 n0/n
      TRA INSAA                      RETURN FOR NEXT a, n
                                     COMBINATION
      REM RESET FOR NEXT FRAME SPACING
INSCY CLA INPUT+5                    a
      FAD INPUT+6                    Δa
      STO INPUT+5                    a
      CAS INPUT+7                    COMPARE a WITH af
      TRA INSCZ                      if a > af
      NOP
      CLA INPUT+8                    n0
      STO ASIDE                      n = n0
      TRA INSCX                      RETURN TO COMPUTE b
      REM RESET TO WORK OUT MINIMUM AREA COMBINATION
INSCZ CLA REMEM+8                    a (min)
      STO INPUT+8                    a0 = a(min)
      STO INPUT+10                   a = a(min)
      CLA REMEM+9                    n (min)
      STO INPUT+5                    n0 = n (min)
      STO INPUT+7                    nf = n (min)
      CLA CONST                      -1.0
```

```
                54 ↑ | 96
        STO TEMP+18 |                    SET CONTROL LOCATION = -1.0
        TRA INSAA ——|                    RETURN TO RECOMPUTE SCANTLINGS
                    |                    FOR MINIMUM AREA
        REM PRINT OUT ROUTINE TO PRINT OUT SCANTLING AND PLATE INFO
        CLA REMEM ←—|                    I,+ (in⁴)
        FDP CONST+30                     144
        STQ REMEM                        I,+ (in² ft²)
        CLA REMEM+1                      I,- (in⁴)
        FDP CONST+30                     144
        STQ REMEM+1                      I,- (in² ft²)
        LXD NIX,1                        RESET INDEX 1
        TSX M,4                          PRINT OUT MOMENTS OF INERTIA
        PZE REMEM,0,REMEM+1
        TSX Q,4                          PRINT OUT LOCATIONS OF NEUTRAL
                                         AXES
        PZE REMEM+2,0,REMEM+3
INSDA   CLA LOC+1,1 ←—|                  z
        TMI OUT ——————|—|                if z=-1, LEAVE LOOP
        CAL CRANK     | |                THE FOLLOWING INSTRUCTIONS
        ACL ONE       | |                PERTAIN TO PRINTING OUT
        SLW ONE       | |                RESULTS OF COMPUTATIONS
        CAL CRANK     | |
        ACL TWO       | |
        SLW TWO       | |
        CAL CRANK     | |
        ACL THREE     | |
        SLW THREE     | |
        CAL CRANK     | |
        ACL FOUR      | |
        SLW FOUR      | |
                      | |
                99 |  | 99 ↓
                                    98
```




```
        TSX N,4                                  PRINT OUT COORDINATES OF
                                                 SCANTLINGS
ONE     PZE LOC-32,0,LOC-30
        TSX WOT,4                                PRINT OUT BEAM DESIGNATION
TWO     PZE LOC-29,0,LOC-27
        TSX 0,4                                  PRINT OUT LENGTH/RADIUS OF
                                                 GYRATION (MAX)
THREE   PZE LOC-26,0,LOC-26
        TSX P,4                                  PRINT OUT PLATE CENTERLINE
                                                 COORDINATES AND PLATE
FOUR    PZE LOC-16,0,LOC-13                      WEIGHT (LB/SQ FT)
INDBV   TXI INSDA,1
OUT     HLT                                      END OF COMPUTATION
L       TRA BLOCK                                PRINT OUT STATEMENTS
        BCD 76H AREA=E15.8,6H   N=F6.1,6H    A=F6.1
M       TRA BLOCK
        BCD 812H INERTIA PL=E15.8,16H    INERTIA MIN=E15.8
Q       TRA BLOCK
        BCD 918H NEUTRAL AXIS SAG=F6.1,19H  NEUTRAL AXIS HOG=F6.1
N       TRA BLOCK
        BCD 810H LOCATION=F6.1,6H   Z=F6.1,6H     Y=F6.1
O       TRA BLOCK
        BCD 627H LENGTH/RADIUS OF GYRATION=F6.1
P       TRA BLOCK
        BCD 910H LOCATION=F6.1,4H  Z=F6.1,4H  Y=F6.1,5H  WT=F6.1
INPUT   BSS 30                                   DEFINITION AND RESERVATION
ASIDE   BSS 15                                   OF STORAGE LOCATIONS IN
                                                 COMPUTER MEMORY
REMEM   BSS 15
LOC     BSS 5000
CONST   DEC -1.0,1.0,2.0,0.29289,-0.4292         CONSTANTS
        DEC 12.0,40000.,1.70,7.7855,-0.04
```

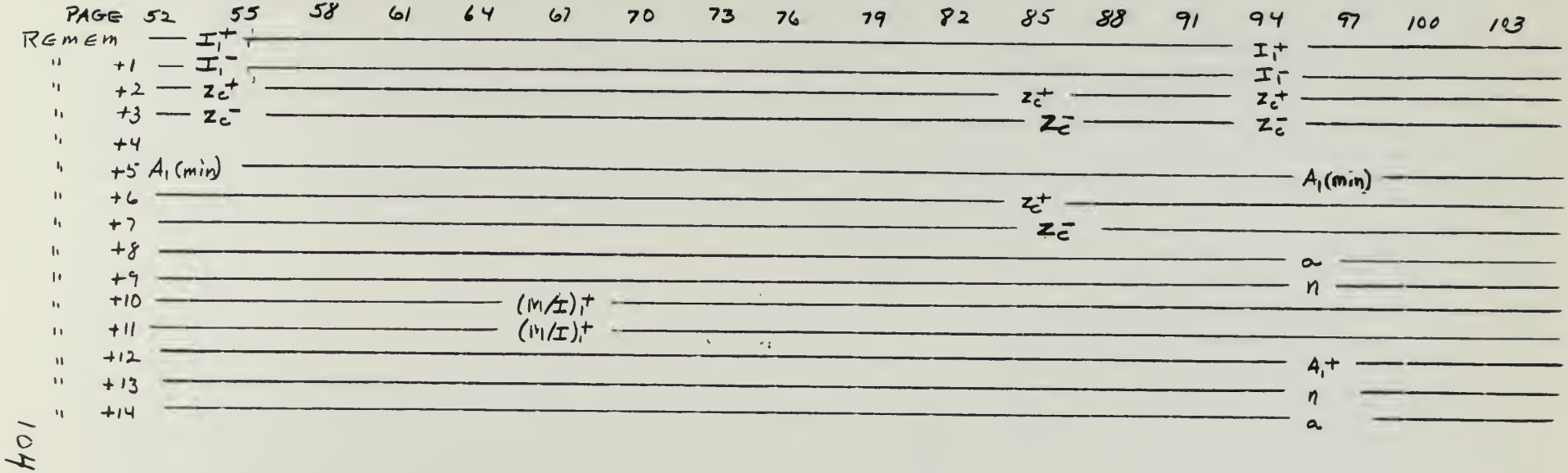
```
      DEC 0.29767,-0.02171546,1.5708,0.8660,0.50
      DEC 10414.,0.0127,30.,18.,324.0
      DEC 54.,9.6,-1.6,-0.88,16970.6,20.,1.5
      DEC 0.90,1.10,2240.0,144.0,0.0,0.0,0.0,0.0,0.0,
TEMP  BSS 40
NIX   PZE
CRANK PZE 32,0,32                    NUMBERS EQUIVALENCE TO 1.
HANDL PZE 0,0,15                     IN [illegible]
      PZE 0,0,31
      PZE 0,0,9
      PZE 0,0,2
00008 TRA INSDF ---+                 ESCAPE FROM FLOATING-TRAP
INSDF SXD TEMP+17,1 |                UNDERFLOW. ACCUMULATOR
      LXD 0,1       |                IS SET TO 0.0 AND CONTROL
      TNX INSDG,1,4 |                IS RETURNED TO MAIN PRO-
      CAL 0         |                GRAM
      HTR           |                IF UNDERFLOW HAS OCCURRED
INSDG CAL 0 <-------+                NUMBER < 10-38
      STA INSDH                      STOP IF OVERFLOW HAS
      PXD 0,0                        OCCURRED NUMBER > 10+38
      LXD TEMP+17,1
INSDH TRA 0 ---------------------->  RETURN TO MAIN PROGRAM
      END START                      END OF PROGRAM
```

```
CST M885-721-PROGRAM
REM INPUT INFORMATION FOR PROGRAM M885
SAP M885-721-INPUT
LST OFF
ORG INPUT
DEC              (FT)  DEPTH
DEC              (FT)  BEAM
DEC              (FT)  BILGE RADIUS
DEC              (FT)  FULL LOAD DRAFT
DEC              (FT)  WAVE CREST HEIGHT ABOVE KEEL
DEC              (IN)  INITIAL FRAME SPACING
DEC              (IN)  INCREMENT OF FRAME SPACING
DEC              (IN)  FINAL FRAME SPACING
DEC                    INITIAL NUMBER OF LONGITUDINALS
DEC                    INCREMENT OF NUMBER OF LONGITUDINALS
DEC                    FINAL NUMBER OF LONGITUDINALS
DEC                    ACCURACY CRITERION FOR MOM. OF INERTIA
DEC           (FT-TONS) BENDING MOMENT SAGGING
DEC           (FT-TONS) BENDING MOMENT HOGGING
DEC              (FT)  MINIMUM HYDROSTATIC HEAD
DEC             (PSI)  ULTIMATE STRENGTH
DEC             (PSI)  YIELD STRENGTH IN TENSION
DEC             (PSI)  YIELD STRENGTH IN COMPRESSION
DEC             (PSI)  YOUNGS MODULUS
DEC             (PSI)  SECONDARY BENDING STRESS AT PLATE
END 0
PMD M885-721-PROGRAM                    POST MORTEM REQUEST
PMR LOC,LOC+1000,FLO,FPR
```

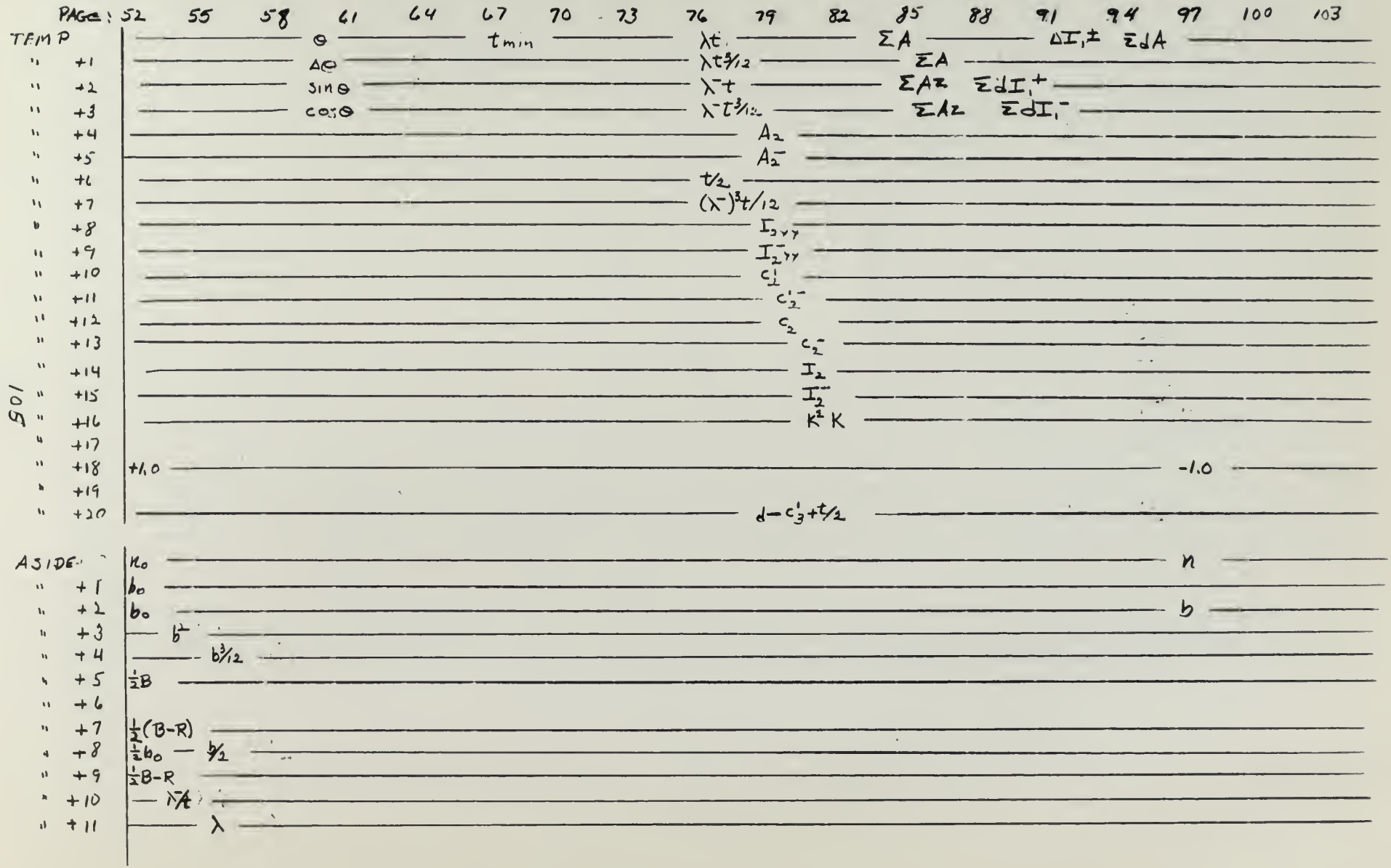
```
CLR
PAK
RIP M885-721-DATA-DAVIS
RIP M885-721-INPUT
RIP M885-721-PROGRAM
BGN M885-721-PROGRAM
XPM M885-721-PROGRAM
TER M885-721-PROGRAM
```

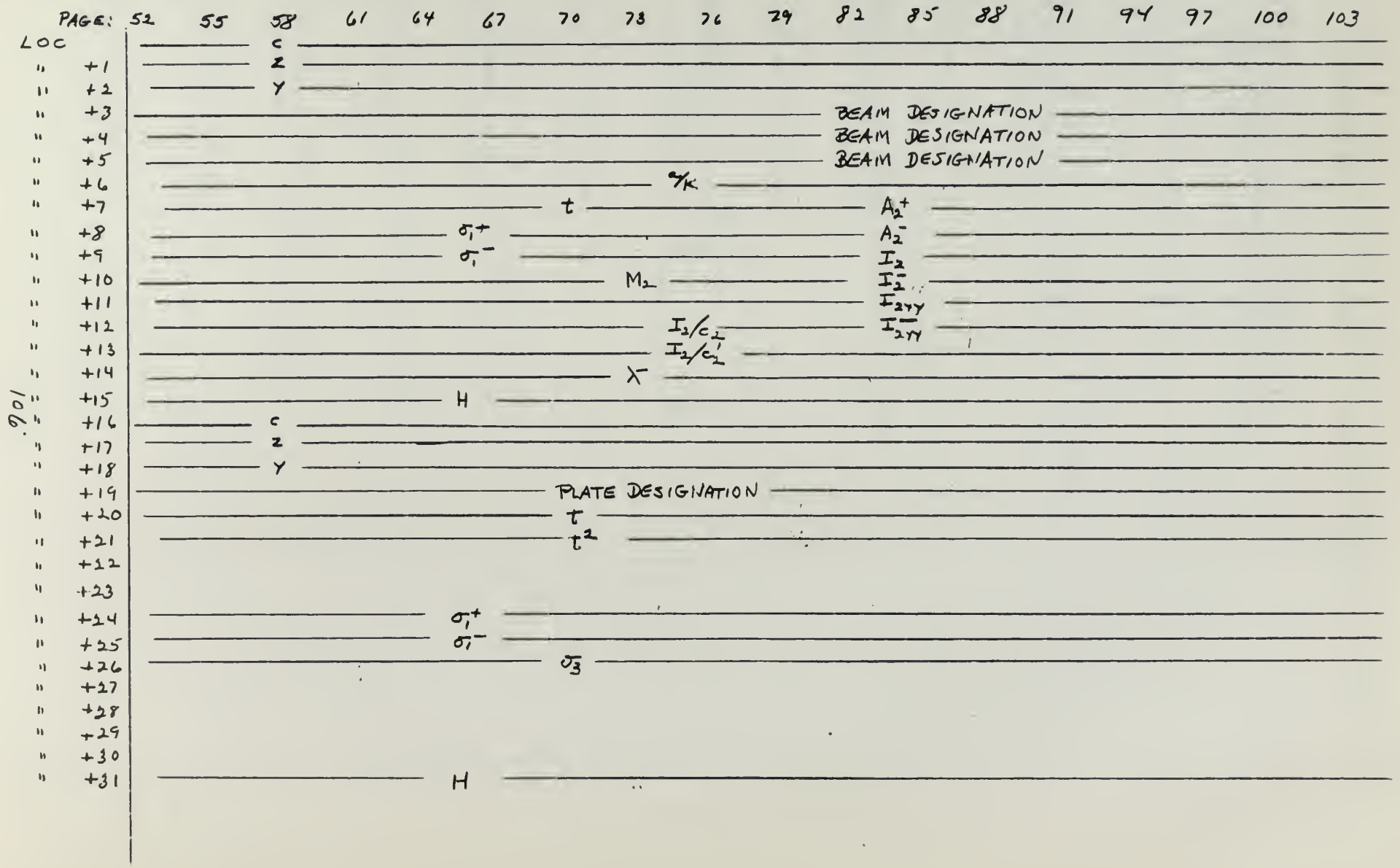
Index of Addresses And Their Contents

CONST	0	-1.0	SCANT	0	BEAM DESIGNATION	PLATE	0	lb/ft^2
"	1	1.0	"	1	" "	"	1	t
"	2	2.0	"	2	" "	"	2	t^2
"	3	0.29289	"	3	A_j			
"	4	-0.4292	"	4	c'_j			
"	5	12.0	"	5	I_j			
"	6	40000.0	"	6	I_{jy_y}			
"	7	1.70	"	7	blank			
"	8	7.7855	"	8	blank			
"	9	-0.04	"	9	d			
"	10	0.29767						
"	11	-0.02171546						
"	12	1.5708	INPUT	0	D			
"	13	0.8660	"	1	B			
"	14	0.50	"	2	R			
"	15	10414.0	"	3	F			
"	16	0.0127	"	4	W			
"	17	30.0	"	5	a_o,a			
"	18	18.0	"	6	Δa			
"	19	324.0	"	7	a_f			
"	20	54.0	"	8	n_o			
"	21	9.6	"	9	Δn			
"	22	-1.6	"	10	n_f			
"	23	-0.88	"	11	ΔI			
"	24	16970	"	12	M_i^+			
"	25	20.0	"	13	M_i^-			
"	26	1.5	"	14	H_o			
"	27	0.90	"	15	σ_{ult}			
"	28	1.10	"	16	σ_{yp}^+			
"	29	2240.0	"	17	σ_{yp}^-			
"	30	144.0	"	18	E			
"	31	5.0	"	19	σ_z			

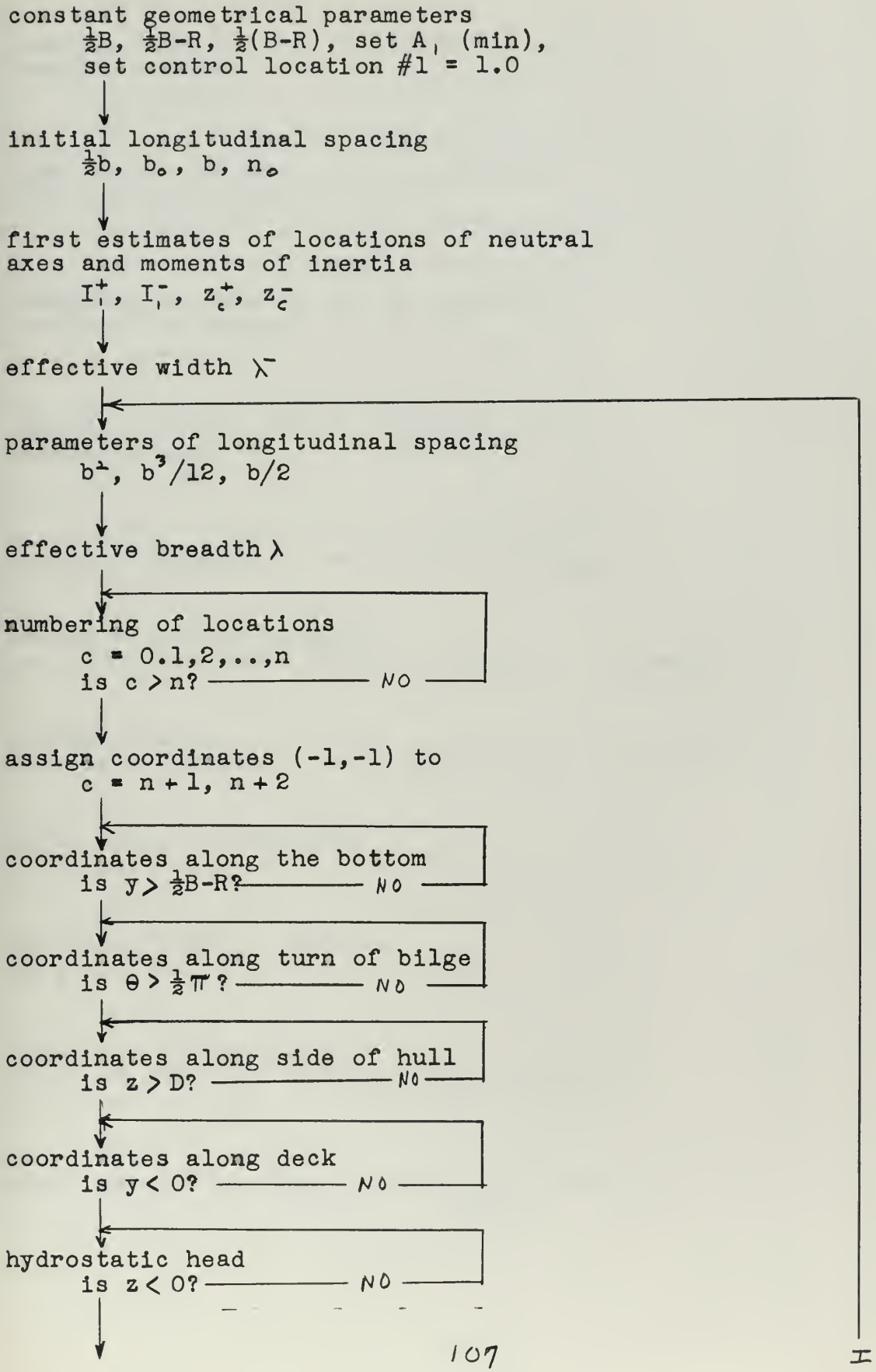

PAGE 52
55
58
61
64
67
70
73
76
79
82
85
88
91
94
97
100
103
REMEM
+1
+2
+3
+4
+5
+6
+7
+8
+9
+10
+11
+12
+13
+14
I_1^+
I_1^-
z_c^+
z_c^-
A_1 (min)
$(M/I)_1^+$
$(M/I)_1^+$
a
n
A_1^+
n
a

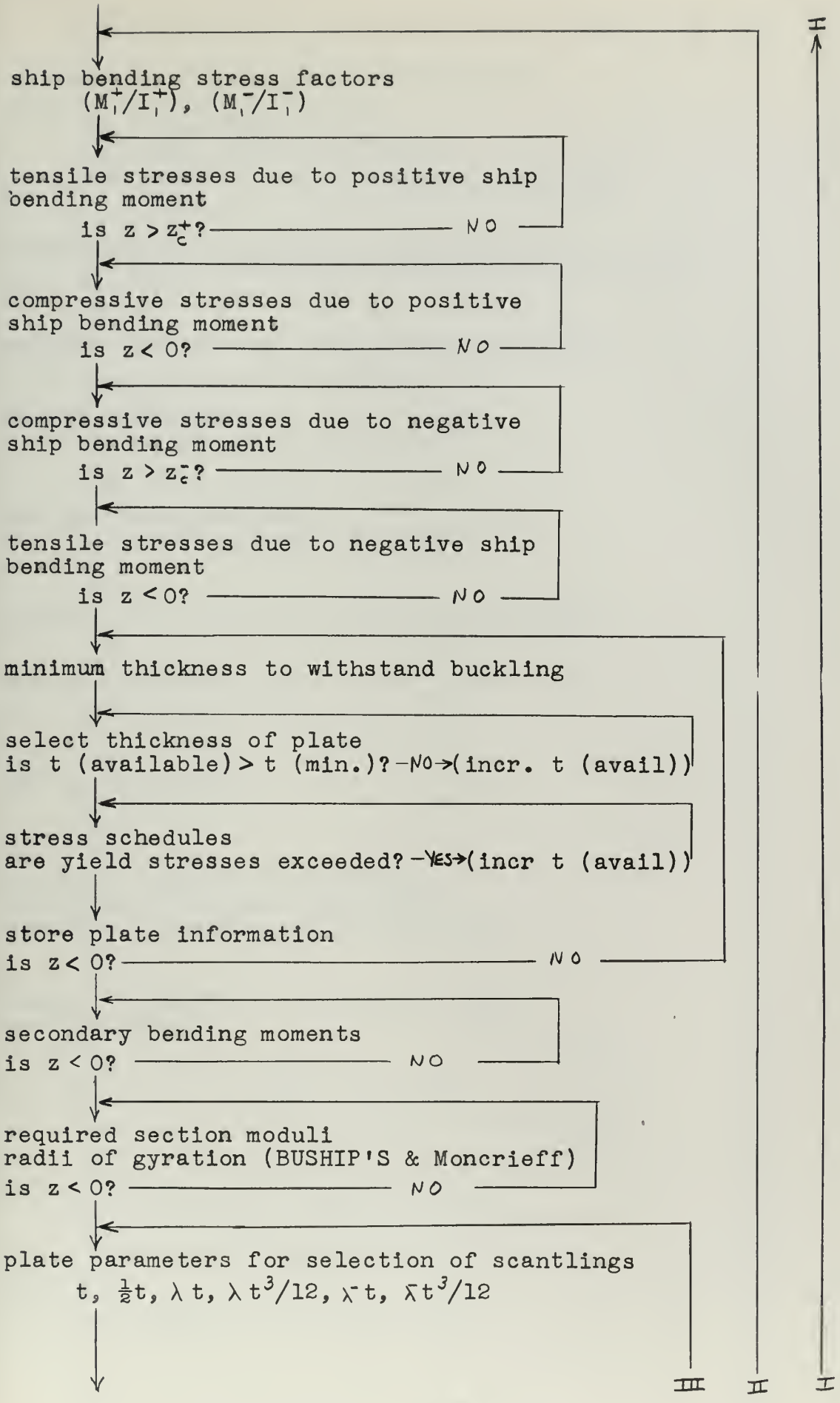
401

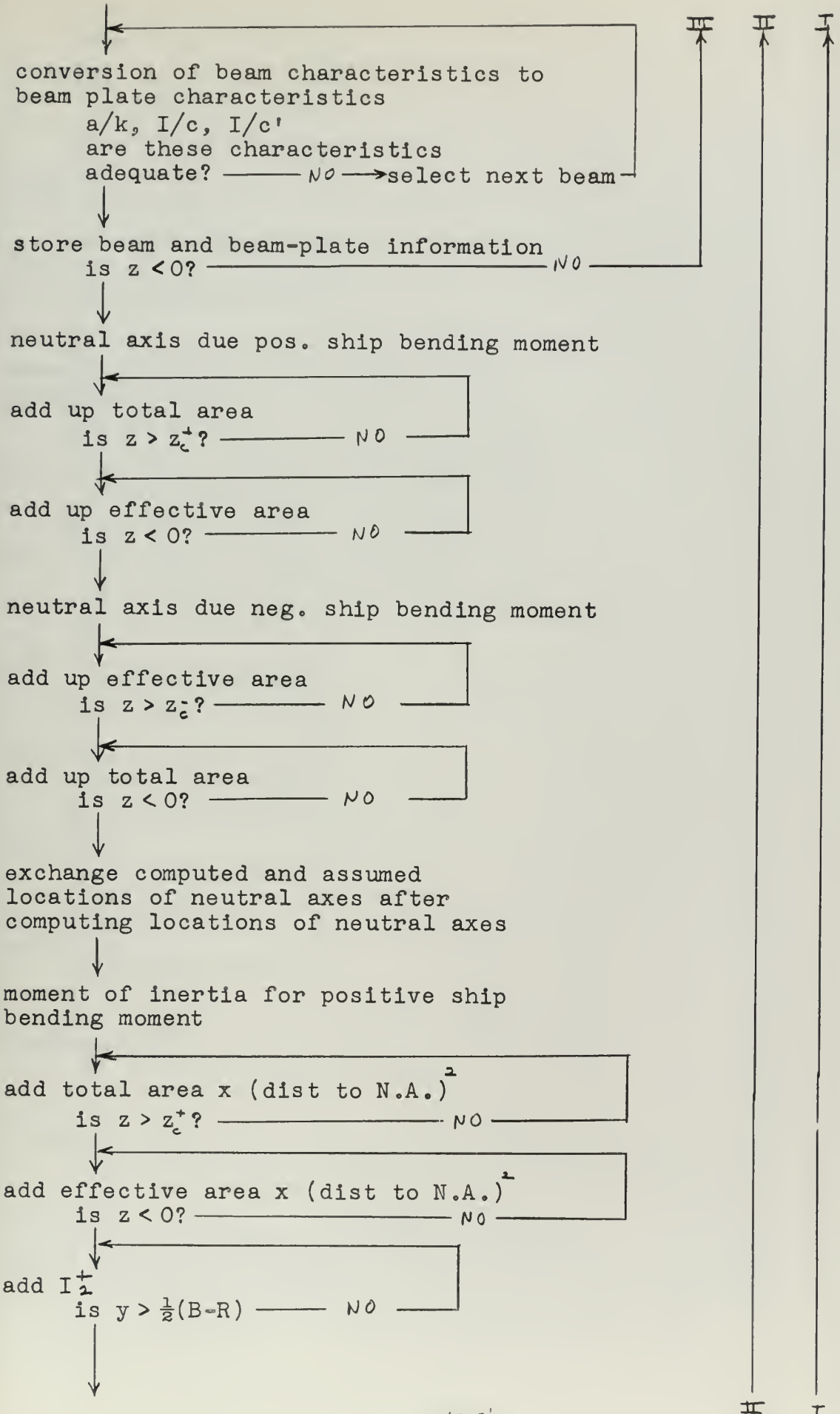

PAGE: 52 55 58 61 64 67 70 73 76 79 82 85 88 91 94 97 100 103
TEMP
501
ASIDE
θ
tmin
λt
ΣA
ΔI,±
ΣdA
Δθ
λt^3/2
ΣA
sinθ
λ^-t
ΣAz
ΣdI,+
cosθ
λ^-t^3/2
ΣAz
ΣdI,-
A2
A2^-
t/2
(λ^-)^3t/12
I3yy
I2^-yy
c1'
c2'^-
c2
c2^-
I2
I2^--
K^2 K
+1.0
-1.0
d-c3'+t/2
κ0
n
b0
b0
b
b^2
b^3/2
½B
½(B-R)
½b0 — b/2
½B-R
— λ^-t
λ

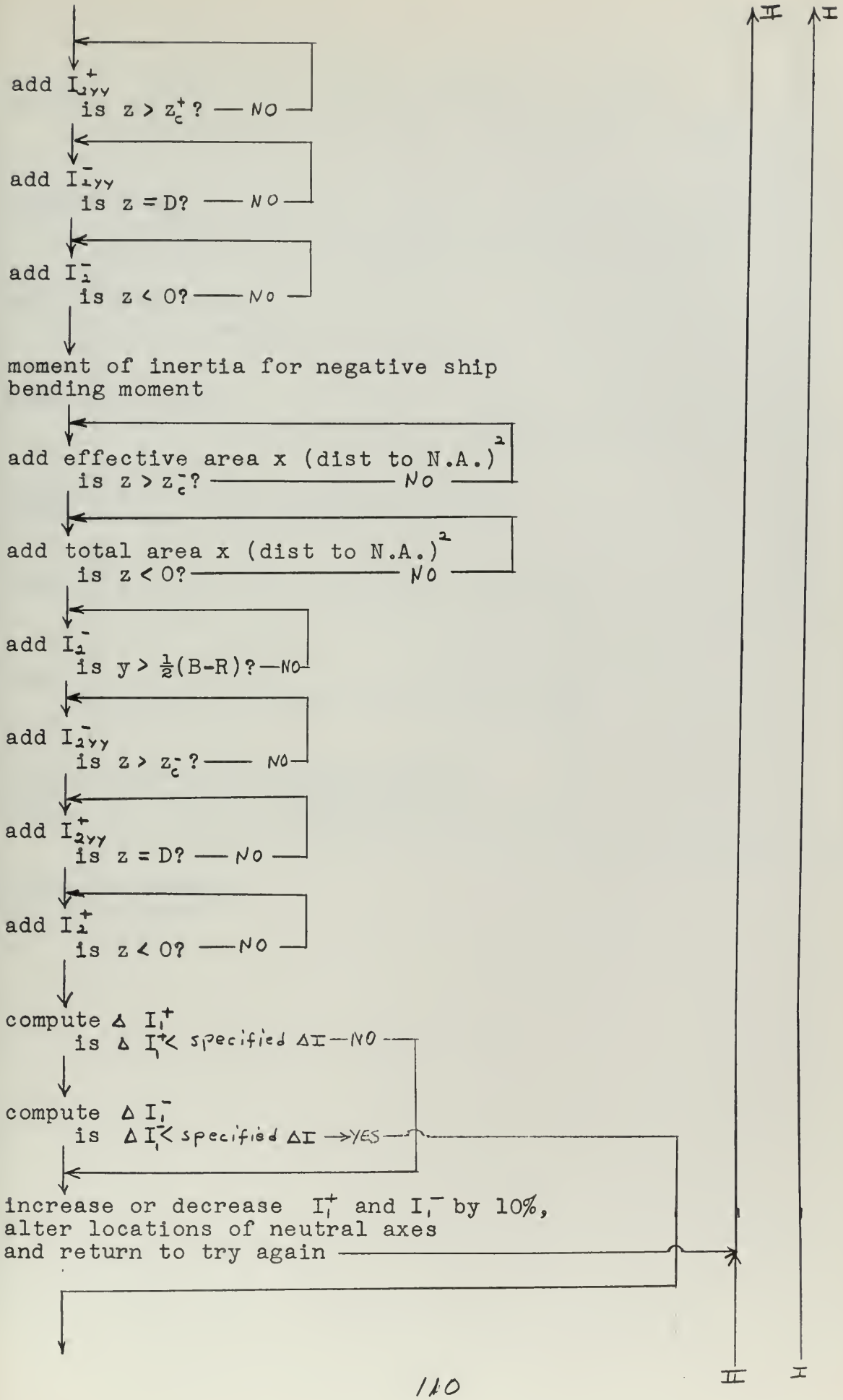

PAGE: 52 55 58 61 64 67 70 73 76 79 82 85 88 91 94 97 100 103
LOC
" +1
" +2
" +3
" +4
" +5
" +6
" +7
" +8
" +9
" +10
" +11
" +12
" +13
" +14
" +15
" +16
" +17
" +18
" +19
" +20
" +21
" +22
" +23
" +24
" +25
" +26
" +27
" +28
" +29
" +30
" +31
901
c
z
y
BEAM DESIGNATION
BEAM DESIGNATION
BEAM DESIGNATION
%/K
t
A_2^+
σ_1^+
A_2^-
σ_1^-
I_2
M_2
I_2^-
I_{2YY}
I_2/c_2
I_{2YY}^-
I_2/c_2'
λ^-
H
c
z
y
PLATE DESIGNATION
t
t^2
σ_1^+
σ_1^-
σ_3
H

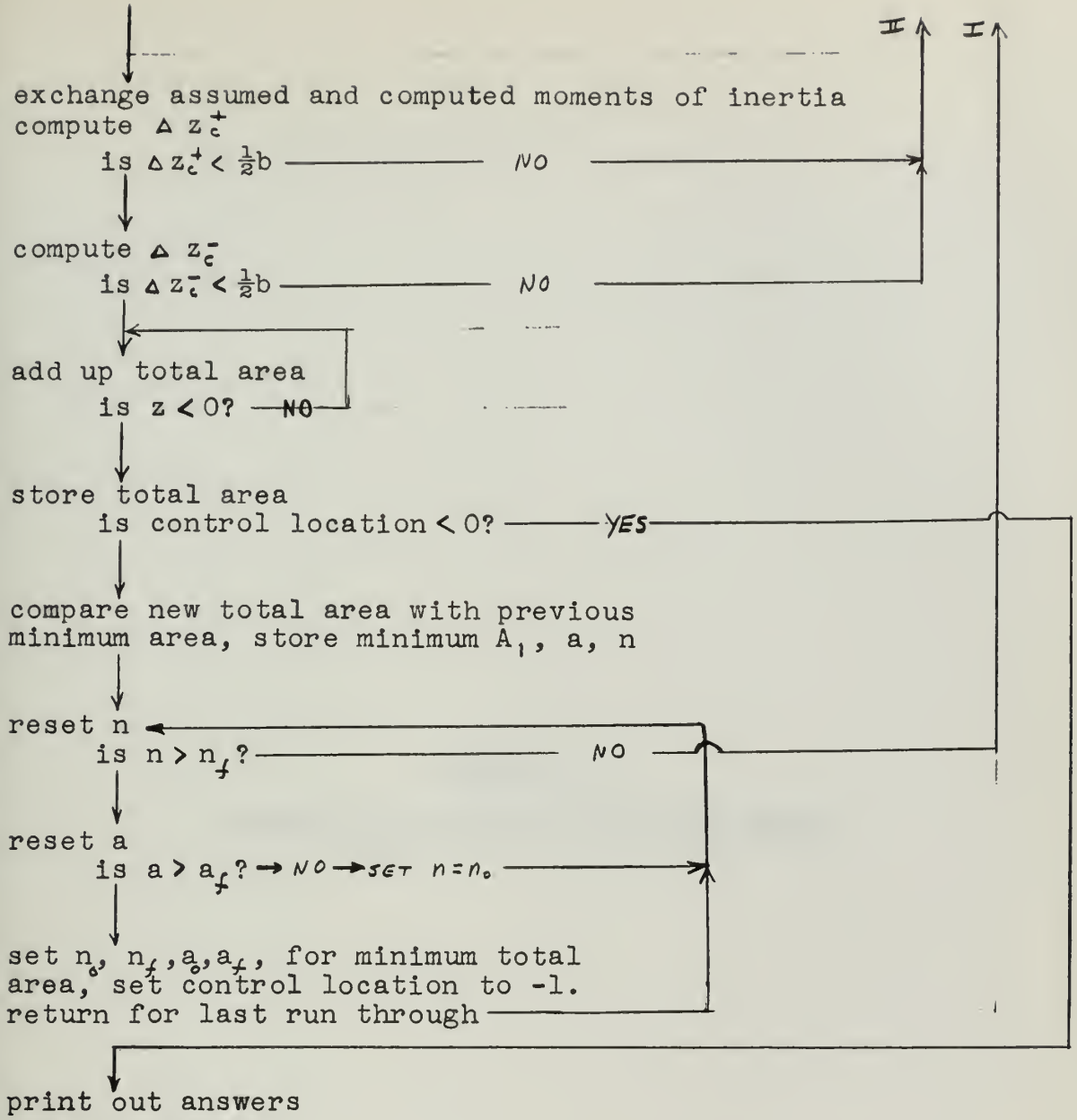
FLOW DIAGRAM FOR SELECTING SCANTLINGS AND PLATING




ship bending stress factors
(M_1^+/I_1^+), (M_1^-/I_1^-)
tensile stresses due to positive ship bending moment
is $z > z_c^+$? NO
compressive stresses due to positive ship bending moment
is $z < 0$? NO
compressive stresses due to negative ship bending moment
is $z > z_c^-$? NO
tensile stresses due to negative ship bending moment
is $z < 0$? NO
minimum thickness to withstand buckling
select thickness of plate
is t (available) > t (min.)? NO → (incr. t (avail))
stress schedules
are yield stresses exceeded? YES → (incr t (avail))
store plate information
is $z < 0$? NO
secondary bending moments
is $z < 0$? NO
required section moduli
radii of gyration (BUSHIP'S & Moncrieff)
is $z < 0$? NO
plate parameters for selection of scantlings
t, $\frac{1}{2}t$, λt, $\lambda t^3/12$, $\lambda^- t$, $\bar{\lambda} t^3/12$
III
II
I
I


conversion of beam characteristics to beam plate characteristics
a/k, I/c, I/c'
are these characteristics adequate?
NO
select next beam
store beam and beam-plate information
is z < 0?
NO
neutral axis due pos. ship bending moment
add up total area
is z > z_c^+?
NO
add up effective area
is z < 0?
NO
neutral axis due neg. ship bending moment
add up effective area
is z > z_c^-?
NO
add up total area
is z < 0?
NO
exchange computed and assumed locations of neutral axes after computing locations of neutral axes
moment of inertia for positive ship bending moment
add total area x (dist to N.A.)^2
is z > z_c^+?
NO
add effective area x (dist to N.A.)^2
is z < 0?
NO
add $I_{\frac{1}{2}}^+$
is y > $\frac{1}{2}$(B-R)
NO
III
II
I
II
I


II
I
add I_{1yy}^{+}
is $z > z_c^{+}$? — NO
add I_{1yy}^{-}
is $z = D$? — NO
add I_1^{-}
is $z < 0$? — NO
moment of inertia for negative ship bending moment
add effective area x (dist to N.A.)^2
is $z > z_c^{-}$? — NO
add total area x (dist to N.A.)^2
is $z < 0$? — NO
add I_1^{-}
is $y > \frac{1}{2}(B-R)$? — NO
add I_{2yy}^{-}
is $z > z_c^{-}$? — NO
add I_{2yy}^{+}
is $z = D$? — NO
add I_1^{+}
is $z < 0$? — NO
compute ΔI_1^{+}
is ΔI_1^{+} < specified ΔI — NO
compute ΔI_1^{-}
is ΔI_1^{-} < specified ΔI → YES
increase or decrease I_1^{+} and I_1^{-} by 10%, alter locations of neutral axes and return to try again
II
I


II
I
exchange assumed and computed moments of inertia
compute Δz_c^+
is $\Delta z_c^+ < \frac{1}{2}b$ — NO
compute Δz_c^-
is $\Delta z_c^- < \frac{1}{2}b$ — NO
add up total area
is $z < 0$? — NO
store total area
is control location < 0? — YES
compare new total area with previous minimum area, store minimum A_1, a, n
reset n
is $n > n_f$? — NO
reset a
is $a > a_f$? → NO → SET $n = n_o$
set n_o, n_f, a_o, a_f, for minimum total area, set control location to -1.
return for last run through
print out answers
end of program

APPENDIX D

PROGRAM FOR DESIGNING THE WEB FRAME

```
        CST M885-721-DATA-DAVIS
        SAP M885-721-PROGRAM
        LST OFF
        PRG OFF
COMMON  SYN/25
MICMD1  SYN/121
 SQRT   SYN /356
 COS    SYN /423
 SIN    SYN /424
 BLOCK  SYN /520
 WOT    SYN /1376
        ORG /10570
 START  CLA HANDL
        COM
        STD INDAA
        STD INDAB
        STD INDAC
        STD INDAD
        STD INDAE
        STD INDAF
        STD INDAG
        STD INDAH
        STD INDAI
        STD INDAJ
        CLA HANDL+1
        COM
        STD INDBA
        STD INDBB
        STD INDBC
        STD INDBD
        STD INDBE
        STD INDBF
        STD INDBG
        STD INDBH
        STD INDBI
        STD INDBJ
        STD INDBK
        STD INDBL
        STD INDBM
        STD INDBN
        STD INDBO
        STD INDBP
        STD INDBQ
        STD INDBR
        STD INDBS
        STD INDBT
        STD INDBU
        STD INDBV
        STD INDBW
        STD INDEA
        STD INDEA
        STD INDEB
        STD INDEC
        STD INDED
        STD INDEE
        STD INDEF
```

THIS PROGRAM IS SIMILAR TO THE PRECEDING PROGRAM FROM THIS PAGE TO PAGE 130. ACCORDINGLY, NO COMMENTS ARE INCLUDED FOR THIS PART.

```
STD INDEG
STD INDEH
STD INDEI
STD INDEJ
STD INDEK
STD INDEL
STD INDEM
CLA HANDL+2
COM
STD INDCA
CLA HANDL+3
COM
STD INDDA
STD INDDB
STD INDDC
STD INDDD
CLA NIX
COM
STD INDFA
EFM
REM CONVERSION OF UNITS
LDQ INPUT
FMP CONST+5
STO INPUT
LDQ INPUT+1
FMP CONST+5
STO INPUT+1
LDQ INPUT+2
FMP CONST+5
STO INPUT+2
LDQ INPUT+3
FMP CONST+5
STO INPUT+3
LDQ INPUT+4
FMP CONST+5
STO INPUT+4
LDQ INPUT+12
FMP CONST+5
STO INPUT+12
LDQ INPUT+13
FMP CONST+5
STO INPUT+13
LDQ INPUT+14
FMP CONST+5
STO INPUT+14
LDQ INPUT+12
FMP CONST+29
STO INPUT+12
LDQ INPUT+13
FMP CONST+29
STO INPUT+13
REM CALCULATION OF CONSTANT GEOMETRICAL PARAMETERS
CLA INPUT+1
FDP CONST+2
STQ ASIDE+5
CLA ASIDE+5
```

```
      FSB INPUT+2
      STO ASIDE+9
      FAD ASIDE+5
      FDP CONST+2
      STQ ASIDE+7
      CLA INPUT+12
      STO REMEM+5
      CLA CONST+1
      STO TEMP+18
      REM CALCULATION OF INITIAL LONGITUDINAL SPACING
      LDQ INPUT+2
      FMP CONST+4
      FAD INPUT
      FAD INPUT+1
      FDP INPUT+8
      STQ ASIDE+8
      FMP CONST+2
      STO ASIDE+1
      STO ASIDE+2
      CLA INPUT+8
      STO ASIDE
      REM CALCULATION OF ESTIMATED MOMENTS OF INERTIA
      LDQ INPUT+12
      FMP INPUT
      FDP CONST+6
      STQ REMEM
      LDQ INPUT+13
      FMP INPUT
      FDP CONST+6
      STQ REMEM+1
      REM FIRST ESTIMATE OF LOCATION OF NEUTRAL AXES
      CLA INPUT
      FDP CONST+2
      STQ REMEM+2
      STQ REMEM+3
      REM CALCULATION OF EFFECTIVE WIDTH (KARMAN SECHLER)
      CLA INPUT+18
      FDP INPUT+17
      STQ TEMP
      CLA TEMP
      TSX SQRT,4
      HTR
      STO TEMP
      LDQ TEMP
      FMP CONST+7
      STO ASIDE+10
      REM CALCULATIONS OF PARAMETERS OF LONGITUDINAL SPACING
INSAA LDQ ASIDE+2
      FMP ASIDE+2
      STQ ASIDE+3
      FDP CONST+5
      FMP ASIDE+2
      STO ASIDE+4
      CLA ASIDE+2
      FDP CONST+2
      STQ ASIDE+8
```

```
      REM EFFECTIVE BREADTH (SCHADE,SNAME TRANS. 11-51)
      LDQ ASIDE+2
      STQ ASIDE+11
      FMP CONST+8
      LDQ INPUT+5
      TLQ INSAB
      TRA INSAC
INSAB LDQ ASIDE+2
      FMP CONST+9
      STO TEMP
      LDQ INPUT+5
      FMP CONST+10
      FAD TEMP
      STO TEMP
      LDQ INPUT+5
      FMP INPUT+5
      FDP ASIDE+2
      FMP CONST+11
      FAD TEMP
      STO ASIDE+11
INSAC LXD NIX,1
      REM NUMBERING OF LOCATIONS, KEEL IS LOCATION ZERO
      CLA NIX
INSAD STO LOC,1
      FAD CONST+1
INDAA TXI INSAE,1
INSAE CAS ASIDE
      TRA INSAF
      NOP
      TRA INSAD
INSAF CLA CONST
      REM COORDINATES OF TWO LOCATIONS BEYOND THE LAST PERTINENT
      REM LOCATION ARE SET AT MINUS ONE TO FACILITATE PROGRAMMING
      STO LOC+1,1
      STO LOC+2,1
      STO LOC+26,1
      STO LOC+27,1
      REM CALCULATION OF LOCATION COORDINATES
      REM COORDINATES ALONG BOTTOM
      LXD NIX,1
      CLA NIX
INSAG STO LOC+2,1
      FAD ASIDE+8
      STZ LOC+1,1
      STZ LOC+17,1
INDAB TXI INSAH,1
INSAH CAS ASIDE+9
      TRA INSAI
      NOP
      TRA INSAG
      REM COORDINATES AT TURN OF BILGE
INSAI FSB ASIDE+9
      FDP INPUT+2
      STQ TEMP
      CLA ASIDE+8
      FDP INPUT+2
```

```
       FSB  INPUT+2
       STO  ASIDE+9
       FAD  ASIDE+5
       FDP  CONST+2
       STQ  ASIDE+7
       CLA  INPUT+12
       STO  REMEM+5
       CLA  CONST+1
       STO  TEMP+18
       REM  CALCULATION OF INITIAL LONGITUDINAL SPACING
       LDQ  INPUT+2
       FMP  CONST+4
       FAD  INPUT
       FAD  INPUT+1
       FDP  INPUT+8
       STQ  ASIDE+8
       FMP  CONST+2
       STO  ASIDE+1
       STO  ASIDE+2
       CLA  INPUT+8
       STO  ASIDE
       REM  CALCULATION OF ESTIMATED MOMENTS OF INERTIA
       LDQ  INPUT+12
       FMP  INPUT
       FDP  CONST+6
       STQ  REMEM
       LDQ  INPUT+13
       FMP  INPUT
       FDP  CONST+6
       STQ  REMEM+1
       REM  FIRST ESTIMATE OF LOCATION OF NEUTRAL AXES
       CLA  INPUT
       FDP  CONST+2
       STQ  REMEM+2
       STQ  REMEM+3
       REM  CALCULATION OF EFFECTIVE WIDTH (KARMAN SECHLER)
       CLA  INPUT+18
       FDP  INPUT+17
       STQ  TEMP
       CLA  TEMP
       TSX  SQRT,4
       HTR
       STO  TEMP
       LDQ  TEMP
       FMP  CONST+7
       STO  ASIDE+10
       REM  CALCULATIONS OF PARAMETERS OF LONGITUDINAL SPACING
INSAA  LDQ  ASIDE+2
       FMP  ASIDE+2
       STQ  ASIDE+3
       FDP  CONST+5
       FMP  ASIDE+2
       STO  ASIDE+4
       CLA  ASIDE+2
       FDP  CONST+2
       STQ  ASIDE+8
```

```
       FMP  CONST+2
       STO  LOC+17,1
       CLA  INPUT
       STO  LOC+1,1
INDAE  TXI  INSAN,1
       REM  BEGINNING OF GENERAL PROGRAM
       REM  CALCULATION OF MAX HYDROSTATIC HEAD EACH LOCATION
INSAO  LXD  NIX,1
INSAP  CLA  LOC+1,1
       TMI  INSAS
       CLA  INPUT+4
       FSB  LOC+1,1
       STO  LOC+16,1
       CLA  INPUT+3
       FSB  LOC+1,1
       STO  TEMP+1
       LDQ  TEMP+1
       FMP  CONST+13
       STO  TEMP+1
       LDQ  LOC+2,1
       FMP  CONST+14
       FAD  TEMP+1
       STO  TEMP+1
       CLA  INPUT+14
       CAS  LOC+16,1
       TRA  INSAQ
       NOP
       CLA  LOC+16,1
INSAQ  STO  LOC+16,1
       CAS  TEMP+1
       TRA  INSAR
       NOP
       CLA  TEMP+1
INSAR  STO  LOC+15,1
INDAF  TXI  INSAP,1
       REM  CALCULATION OF SHIP (PRIMARY) BENDING STRESSES
INSAS  LXD  NIX,1
       CLA  INPUT+12
       FDP  REMEM
       STQ  REMEM+10
       CLA  INPUT+13
       FDP  REMEM+1
       STQ  REMEM+11
       REM  STRESSES DUE TO POSITIVE SHIP BENDING MOMENT
INSAT  CLA  REMEM+2
       FSB  LOC+1,1
       TMI  INSAU
       STO  TEMP
       LDQ  TEMP
       FMP  REMEM+10
       STO  LOC+8,1
INDAG  TXI  INSAT,1
INSAU  CLA  LOC+1,1
       TMI  INSAV
       FSB  REMEM+2
       STO  TEMP
```

```
       LDQ TEMP
       FMP REMEM+10
       STO LOC+9,1
INDAH  TXI INSAU,1
       REM STRESSES DUE TO NEGATIVE SHIP BENDING MOMENT
INSAV  LXD NIX,1
INSAW  CLA REMEM+3
       FSB LOC+1,1
       TMI INSAX
       STO TEMP
       LDQ TEMP
       FMP REMEM+11
       STO LOC+9,1
INDAI  TXI INSAW,1
INSAX  CLA LOC+1,1
       TMI INSAY
       FSB REMEM+3
       STO TEMP
       LDQ TEMP
       FMP REMEM+11
       STO LOC+8,1
INDAJ  TXI INSAX,1
       REM SELECTION OF HULL PLATING BRYAN BUCKLING CRITERIA
INSAY  LXD NIX,3
INSAZ  CLA LOC+26,1
       TMI INSBC
       CLA LOC+34,1
       TSX SQRT,4
       HTR
       FDP CONST+15
       FMP ASIDE+2
       STO TEMP
       REM SELECTION OF PLATING THICKNESS FROM STD STOCK
INSBA  CLA PLATE,2
       TMI INDDC+2
       CLA TEMP
       CAS PLATE+1,2
INDDA  TXI INSBA,2
       REM TERTIARY STRESS CALCULATION
       NOP
INSBB  LDQ ASIDE+3
       FMP LOC+40,1
       FDP PLATE+2,2
       FMP CONST+16
       STO LOC+35,1
       STO LOC+85,1
       REM STRESS SCHEDULE BETWEEN LONGITUDINALS
       FAD LOC+33,1
       FAD INPUT+19
       CAS INPUT+16
INDDB  TXI INSBB,2
       NOP
       CLA LOC+34,1
       FAD LOC+35,1
       FSB INPUT+19
       CAS INPUT+17
```

```
INDDC TXI INSBB,2
      NOP
      CLA PLATE,2
      STO LOC+28,1
      CLA PLATE+1,2
      STO LOC+29,1
      STO LOC+79,1
      CLA PLATE+2,2
      STO LOC+30,1
      LXD NIX,2
INDBA TXI INSAZ,1
INSBC LXD NIX,3
      REM PLATE THICKNESSES TO BE ASSOCIATED WITH SCANTLINGS
      LDQ LOC+29
      STQ LOC+7
      FMP ASIDE+10
      CAS ASIDE+2
      CLA ASIDE+2
      NOP
      STO LOC+14
INDBB TXI INSBD,1
INSBD CLA LOC+1,1
      TMI INSBF
      CLA LOC-21,1
      FAD LOC+29,1
      FDP CONST+2
      STQ LOC+7,1
      STQ LOC+57,1
      FMP ASIDE+10
      CAS ASIDE+2
      CLA ASIDE+2
      NOP
      STO LOC+14,1
      TRA INDBB
INSBF LXD NIX,1
      REM CALCULATION OF SECONDARY BENDING MOMENTS
      LDQ INPUT+5
      FMP INPUT+5
      FDP CONST+19
      FMP ASIDE+2
      STO TEMP
INSBG CLA LOC+1,1
      TMI INSBH
      LDQ LOC+15,1
      FMP TEMP
      STO LOC+10,1
INDBC TXI INSBG,1
INSBH LXD NIX,1
      REM REQUIRED SECTION MODULI
INSBI CLA LOC+1,1
      TMI INSBN
      CLA INPUT+17
      FSB LOC+9,1
      FDP CONST+26
      STQ TEMP
      CLA INPUT+16
```

```
        FSB LOC+8,1
        FSB LOC+35,1
        CAS TEMP
        CLA TEMP
        NOP
        STO TEMP
        CLA LOC+10,1
        FDP TEMP
        STQ LOC+12,1
        CLA INPUT+16
        FSB LOC+8,1
        FDP CONST+26
        STQ TEMP
        CLA INPUT+17
        FSB LOC+9,1
        CAS TEMP
        CLA TEMP
        NOP
        STO TEMP
        CLA LOC+10,1
        FDP TEMP
        STQ LOC+13,1
        REM SPAN/RADIUS OF GYRATION. BUSHIPS CRITERION
        CLA LOC+1,1
        FDP INPUT
        FMP CONST+25
        FAD CONST+17
        STO LOC+6,1
        REM SPAN/RADIUS OF GYRATION, MONCRIEFF  FACTOR OF SAFETY = 1.0
        CLA LOC+9,1
        FSB INPUT+19
        TMI INDBD
        LDQ LOC+9,1
        FMP CONST+22
        FAD INPUT+15
        TMI INDBD
        FDP LOC+9,1
        STQ TEMP
        LDQ LOC+9,1
        FMP CONST+23
        FAD INPUT+15
        STO TEMP+1
        CLA TEMP
        FDP TEMP+1
        STQ TEMP
        CLA TEMP
        TSX SQRT,4
        TRA INDBD
        STO TEMP
        LDQ TEMP
        FMP CONST+24
        REM COMPARISON  OF RADII  OF GYRATION8 THE LESSER VALUE IS USED
        CAS LOC+6,1
        CLA LOC+6,1
        NOP
INSBM   STO LOC+6,1
```

```
INDBD TXI INSBI,1
      REM PLATE PARAMETERS FOR SELECTION OF SCANTLINGS
INSBN LXD NIX,3
INSBO CLA LOC+1,1
      TMI INSBQ
      LXD NIX,2
      CLA LOC+7,1
      FDP CONST+2
      STQ TEMP+6
      LDQ LOC+7,1
      FMP ASIDE+11
      STO TEMP
      LDQ TEMP
      FMP LOC+7,1
      FDP CONST+5
      FMP LOC+7,1
      STO TEMP+1
      LDQ LOC+14,1
      FMP LOC+7,1
      STO TEMP+2
      FDP CONST+5
      FMP LOC+14,1
      STO TEMP+7
      LDQ TEMP+7
      FMP LOC+14,1
      STO TEMP+7
      CLA TEMP+1
      FDP ASIDE+11
      FMP LOC+14,1
      STO TEMP+3
      REM CONVERSION OF BEAM CHARACTERISTICS TO BEAM PLATE
      REM CHARACTERISTICS, AREA, LOCATION NA, MOMENT OF INERTIA
      REM CALCULATION OF EFFECTIVE AREAS
INSBP CLA SCANT+3,2
      TMI INDCA+10
      FAD TEMP
      STO TEMP+4
      CLA SCANT+3,2
      FAD TEMP+2
      STO TEMP+5
      REM CALCULATION OF EFFECTIVE I (YY)
      LDQ ASIDE+4
      FMP LOC+7,1
      FAD SCANT+6,2
      STO TEMP+8
      CLA TEMP+7
      FAD SCANT+6,2
      STO TEMP+9
      REM CALCULATIO  OF NEUTRAL AXES
      CLA SCANT+9,2
      FSB SCANT+4,2
      FAD TEMP+6
      STO TEMP+20
      FDP TEMP+4
      FMP TEMP
      FAD SCANT+4,2
```

```
STO TEMP+10
CLA TEMP+20
FDP TEMP+5
FMP TEMP+2
FAD SCANT+4,2
STO TEMP+11
REM  CALCULATION OF EFFECTIVE MOMENTS OF INERTIA
FSB SCANT+4,2
STO TEMP+15
LDQ TEMP+15
FMP TEMP+15
STO TEMP+15
LDQ TEMP+15
FMP SCANT+3,2
FAD SCANT+5,2
STO TEMP+15
CLA TEMP+10
FSB SCANT+4,2
STO TEMP+14
LDQ TEMP+14
FMP TEMP+14
STO TEMP+14
LDQ TEMP+14
FMP SCANT+3,2
FAD SCANT+5,2
STO TEMP+14
CLA SCANT+9,2
FAD LOC+7,1
STO TEMP+16
FSB TEMP+10
STO TEMP+12
CLA TEMP+16
FSB TEMP+11
STO TEMP+13
FSB TEMP+6
STO TEMP+16
LDQ TEMP+16
FMP TEMP+16
STO TEMP+16
LDQ TEMP+16
FMP TEMP+2
FAD TEMP+3
FAD TEMP+15
STO TEMP+15
CLA TEMP+12
FSB TEMP+6
STO TEMP+16
LDQ TEMP+16
FMP TEMP+16
STO TEMP+16
LDQ TEMP+16
FMP TEMP
FAD TEMP+1
FAD TEMP+14
STO TEMP+14
REM CALCULATION OF RADIUS OF GYRATION
```

```
        CLA TEMP+15
        FDP TEMP+5
        STQ TEMP+16
        CLA TEMP+16
        TSX SQRT,4
        HTR
        STO TEMP+16
        REM CALCULATION OF SPAN/RADIUS OF GYRATION
        CLA INPUT+5
        FDP TEMP+16
        STQ TEMP+16
        CLA TEMP+16
        REM TEST OF SELECTED SCANTLING
        CAS LOC+6,1
INDCA   TXI INSBP,2
        NOP
        CLA TEMP+14
        FDP TEMP+12
        CLA LOC+12,1
        TLQ INDCA
        CLA TEMP+14
        FDP TEMP+10
        CLA LOC+13,1
        TLQ INDCA
        REM STORING DESCRIPTION AND PROPERTIES OF SELECEED SCANTLING
        CLA SCANT,2
        STO LOC+3,1
        CLA SCANT+1,2
        STO LOC+4,1
        CLA SCANT+2,2
        STO LOC+5,1
        LDQ LOC+7,1
        FMP ASIDE+2
        FAD SCANT+3,2
        STO LOC+11,1
        CLA TEMP+5
        STO LOC+20,1
        CLA TEMP+14
        STO LOC+21,1
        CLA TEMP+15
        STO LOC+22,1
        CLA TEMP+8
        STO LOC+23,1
        CLA TEMP+9
        STO LOC+24,1
INDBE   TXI INSBO,1
        REM LOCATION OF NEUTRAL AXES, ACCURACY TO HALF SCANT SPACE
        REM NEUTRAL AXIS FOR SHIP SAGGING
INSBQ   LXD NIX,3
        STZ TEMP
        STZ TEMP+1
        STZ TEMP+2
        STZ TEMP+3
INSBR   CLA LOC+1,1
        TMI INSBT
        CLA REMEM+2
```

```
        FSB LOC+1,1
        TMI INSBS
        CLA TEMP
        FAD LOC+11,1
        STO TEMP
        LDQ LOC+11,1
        FMP LOC+1,1
        FAD TEMP+2
        STO TEMP+2
INDBF   TXI INSBR,1
INSBS   CLA TEMP
        FAD LOC+20,1
        STO TEMP
        LDQ LOC+20,1
        FMP LOC+1,1
        FAD TEMP+2
        STO TEMP+2
INDBG   TXI INSBR,1
INSBT   LXD NIX,1
        CLA TEMP+2
        FDP TEMP
        CLA REMEM+2
        STO REMEM+6
        STQ REMEM+2
        REM NEUTRAL AXIS FOR SHIP HOGGING
INSBY   CLA LOC+1,1
        TMI INSCA
        CLA REMEM+3
        FSB LOC+1,1
        TMI INSBZ
        CLA TEMP+1
        FAD LOC+20,1
        STO TEMP+1
        LDQ LOC+20,1
        FMP LOC+1,1
        FAD TEMP+3
        STO TEMP+3
INDBH   TXI INSBY,1
INSBZ   CLA TEMP+1
        FAD LOC+11,1
        STO TEMP+1
        LDQ LOC+11,1
        FMP LOC+1,1
        FAD TEMP+3
        STO TEMP+3
INDBW   TXI INSBY,1
INSCA   CLA TEMP+3
        FDP TEMP+1
        CLA REMEM+3
        STO REMEM+7
        STQ REMEM+3
        LXD NIX,1
        STZ TEMP+2
        STZ TEMP+3
        REM MOM OF INERTIA FOR POSITIVE SHIP BENDING MOMENT
        REM EFFECTIVE AREAS TIMES DISTANCES TO NEUTRAL AXIS SQUARED
```

```
INSCF CLA LOC+1,1
      TMI INSCH
      CLA REMEM+2
      FSB LOC+1,1
      TMI INSCG
      STO TEMP
      LDQ TEMP
      FMP TEMP
      STO TEMP
      LDQ TEMP
      FMP LOC+11,1
      FAD TEMP+2
      STO TEMP+2
INDBI TXI INSCF,1
INSCG CLA LOC+1,1
      FSB REMEM+2
      STO TEMP
      LDQ TEMP
      FMP TEMP
      STO TEMP
      LDQ TEMP
      FMP LOC+20,1
      FAD TEMP+2
      STO TEMP+2
INDBJ TXI INSCF,1
      REM MOMENTS OF INERTIA ALONG THE BOTTOM OF HULL
INSCH LXD NIX,1
INSCI LDQ ASIDE+7
      CLA LOC+2,1
      TLQ INSCJ
      CLA LOC+21,1
      FAD TEMP+2
      STO TEMP+2
INDBK TXI INSCI,1
      REM MOMENTS OF INERTIA ALONG SIDE OF HULL BELOW NEUTRAL AXIS
INSCJ CLA LOC+1,1
      CAS INPUT
      NOP
      TRA INSCL
      CLA REMEM+2
      FSB LOC+1,1
      TMI INSCK
      CLA LOC+23,1
      FAD TEMP+2
      STO TEMP+2
INDBL TXI INSCJ,1
      REM MOMENTS OF INERTIA ALONG SIDE OF HULL ABOVE NEUTRAL AXIS
INSCK CLA LOC+24,1
      FAD TEMP+2
      STO TEMP+2
INDBM TXI INSCJ,1
      REM MOMENTS OF INERTIA ALONG THE DECK
INSCL CLA LOC+1,1
      TMI INSCM
      CLA LOC+22,1
      FAD TEMP+2
```

```
        STO TEMP+2
INDBN   TXI INSCL,1
INSCM   LXD NIX,1
        REM MOMENT OF INERTIA FOR NEGATIVE BENDING MOMENT
        REM EFFECTIVE AREAS TIMES DISTANCES TO NEUTRAL AXIS SQUARED
INSCN   CLA LOC+1,1
        TMI INSCP
        CLA REMEM+3
        FSB LOC+1,1
        TMI INSCO
        STO TEMP+1
        LDQ TEMP+1
        FMP TEMP+1
        STO TEMP+1
        LDQ TEMP+1
        FMP LOC+20,1
        FAD TEMP+3
        STO TEMP+3
INDBO   TXI INSCN,1
INSCO   CLA LOC+1,1
        FSB REMEM+3
        STO TEMP+1
        LDQ TEMP+1
        FMP TEMP+1
        STO TEMP+1
        LDQ TEMP+1
        FMP LOC+11,1
        FAD TEMP+3
        STO TEMP+3
INDBP   TXI INSCN,1
        REM MOMENTS OF INERTIA ALONG THE BOTTOM OF HULL
INSCP   LXD NIX,1
INSCQ   LDQ ASIDE+7
        CLA LOC+2,1
        TLQ INSCR
        CLA LOC+22,1
        FAD TEMP+3
        STO TEMP+3
INDBQ   TXI INSCQ,1
        REM MOMENTS OF INERTIA ALONG SIDE OF HULL BELOW NEUTRAL AXIS
INSCR   CLA LOC+1,1
        CAS INPUT
        NOP
        TRA INSCT
        CLA REMEM+3
        FSB LOC+1,1
        TMI INSCS
        CLA LOC+24,1
        FAD TEMP+3
        STO TEMP+3
INDBR   TXI INSCR,1
        REM MOMENTS OF INERTIA ALONG SIDE OF HULL ABOVE NEUTRAL AXIS
INSCS   CLA LOC+23,1
        FAD TEMP+3
        STO TEMP+3
INDBS   TXI INSCR,1
```

```
      REM MOMENTS OF INERTIA ALONG THE DECK
INSCT CLA LOC+1,1
      TMI INSCU
      CLA LOC+21,1
      FAD TEMP+3
      STO TEMP+3
INDBT TXI INSCT,1
INSCU LXD NIX,1
      TSX M,4
      PZE REMEM,0,REMEM+1
      TSX Q,4
      PZE REMEM+2,0,REMEM+3
      REM ACCURACY TEST FOR MOMENTS OF INERTIA
      CLA TEMP+3
      FSB REMEM+1
      FDP REMEM+1
      STQ TEMP
      CLA TEMP
      SSP
      CAS INPUT+11
      NOP
      TRA BACK
      CLA TEMP+2
      FSB REMEM
      FDP REMEM
      STQ TEMP
      CLA TEMP
      SSP
      CAS INPUT+11
      NOP
      TRA BACK
      TRA INSCV
      REM ACCURA Y CRITERIA FOR SHIP MOMENTS OF INERTIA HAS FAILED,
      REM THE FOLLOWING INSTRUCTIONS MODIFY SHIPS MOMENT OF INERTIA
BACK  CLA REMEM+6
      FAD REMEM+2
      FDP CONST+2
      STQ REMEM+2
      CLA REMEM+7
      FAD REMEM+3
      FDP CONST+2
      STQ REMEM+3
      CLA REMEM
      CAS TEMP+2
      TRA INSDC
      NOP
      LDQ CONST+28
      FMP REMEM
      STO REMEM
      TRA INSDD
INSDC LDQ CONST+27
      FMP REMEM
      STO REMEM
INSDD CLA REMEM+1
      CAS TEMP+3
      TRA INSDE
```

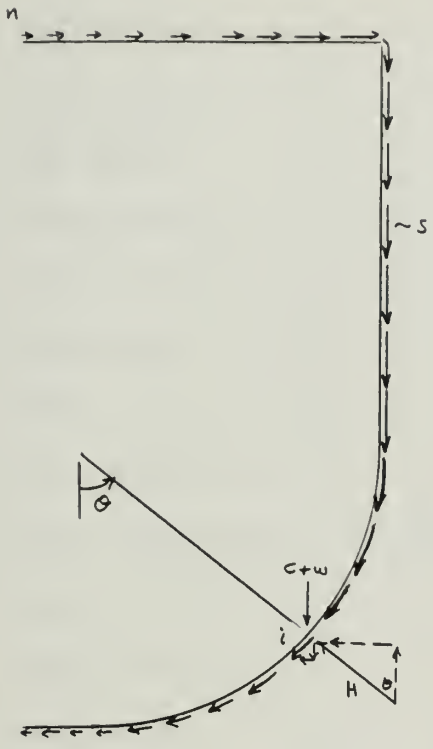
```
       NOP
       LDQ CONST+28
       FMP REMEM+1
       STO REMEM+1
       TRA INSAS
INSDE  LDQ CONST+27
       FMP REMEM+1
       STO REMEM+1
       TRA INSAS
       REM ACCURACY TESTS FOR LOCATIONS OF NEUTRAL AXES
INSCV  CLA TEMP+3
       STO REMEM+1
       CLA TEMP+2
       STO REMEM
       CLA REMEM+6
       FSB REMEM+2
       SSP
       CAS ASIDE+8
       NOP
       TRA INSAS
       CLA REMEM+7
       FSB REMEM+3
       SSP
       CAS ASIDE+8
       NOP
       TRA INSAS
       REM CALCULATION OF TOTAL CROSS SECTION AREA
       STZ TEMP
INSBX  CLA LOC+1,1
       TMI INSCW
       CLA LOC+11,1
       FAD TEMP
       STO TEMP
INDBU  TXI INSBX,1
       REM STORE AREA, NR SCANTLINGS AND FRAME SPACING
INSCW  CLA TEMP
       STO REMEM+12
       CLA ASIDE
       STO REMEM+13
       CLA INPUT+5
       STO REMEM+14
       TSX L,4
       PZE REMEM+12,0,REMEM+14
       REM PRINT OUT ROUTINE TO PRINT OUT SCANTLING AND PLATE INFO
       CLA REMEM
       FDP CONST+30
       STQ REMEM
       CLA REMEM+1
       FDP CONST+30
       STQ REMEM+1
       LXD NIX,1
       TSX M,4
       PZE REMEM,0,REMEM+1
       TSX Q,4
       PZE REMEM+2,0,REMEM+3
INSDA  CLA LOC+1,1
```

```
        ACL ONE
        SLW ONE
        CAL CRANK
        ACL TWO
        SLW TWO
        CAL CRANK
        ACL THREE
        SLW THREE
        CAL CRANK
        ACL FOUR
        SLW FOUR
        TSX N,4
ONE     PZE LOC-50,0,LOC-48
        TSX WOT,4
TWO     PZE LOC-47,0,LOC-45
        TSX 0,4
THREE   PZE LOC-44,0,LOC-44
        TSX P,4
FOUR    PZE LOC-25,0,LOC-22
INDBV   TXI INSDA,1

        REM FIRST AND SECOND MOMENTS OF AREAS

OUT     STZ TEMP <- - -          SET TO ZERO

        STZ TEMP+1               SET TO ZERO

        STZ TEMP+2               SET TO ZERO

        STZ TEMP+3               SET TO ZERO

        LXD NIX,1                RESET INDEX 1

INSEA   CLA LOC+1,1 <-           Z

        TMI INSEB - - -          IF Z=-1 LEAVE LOOP

        CLA LOC+11,1             A2+

        FAD TEMP                 ΣA

        STO TEMP                 ΣA

        LDQ LOC+11,1             A2+

        FMP LOC+1,1              Z

        FAD TEMP+1               ΣAZ

        STO TEMP+1               ΣAZ

        LDQ LOC+1,1              Z

        FMP LOC+1,1              Z

                  131 |  131
```

```
                STO  TEMP+4          z^2
                LDQ  LOC+11,1        A_2^+
                FMP  TEMP+4          z^2
                FAD  TEMP+2          Σ A z^2
                STO  TEMP+2          Σ A z^2
INDEA           TXI  INSEA,1
INSEB           CLA  TEMP+1          Σ A z
                FDP  TEMP            Σ A
                STQ  TEMP+1          z_c
                FMP  TEMP+1          z_c
                STO  TEMP+4          z_c^2
                LDQ  TEMP            Σ A
                FMP  TEMP+4          z_c^2
                CHS
                FAD  TEMP+2          Σ A z^2
                STO  TEMP+2          I = Σ A z^2 - z_c^2 Σ A
                LXD  NIX,1           RESET INDEX 1
INSEC           CLA  LOC+1,1         z
                TMI  INSED           IF z = -1, LEAVE LOOP
                FSB  TEMP+1          z_c
                CHS
                STO  TEMP+5          z_c - z
                LDQ  LOC+11,1        A_2^+
                FMP  TEMP+5          z_c - z
                FAD  TEMP+3          Σ A_2^+ (z_c - z)
                STO  TEMP+3          Σ A_2^+ (z_c - z)
                STO  LOC+20,1        Q_n = Σ_{n=0}^{n=n} A_{2n}^+ (z_c - z_n)
INDEB           TXI  INSEC,1
```

130 ↑ 130

↓ 133.



$$V = \sum_{0}^{n} (H_i \cos\theta_i - (c+w)_i)$$

$$V = \sum_{0}^{n} S_i \sin\theta_i$$

$$S_i = \tau_i b t_i$$

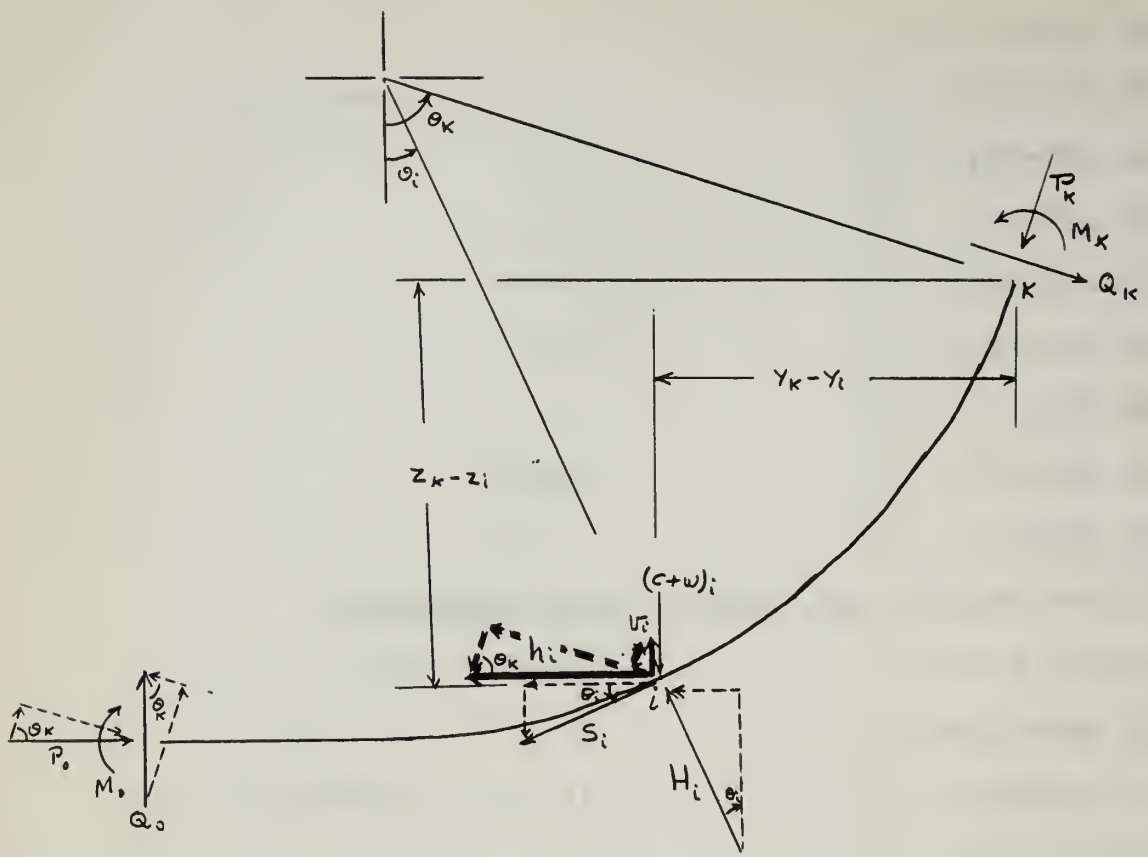
$$\tau_i = \frac{VQ_i}{t_i I}$$

$$\therefore S_i = Q_i \left(\frac{Vb}{I}\right)$$

WHERE,

$$Q = \sum_{0}^{i} A_{2_i}^{+} (z_c - z_i)$$

```
                                132
INSED LXD NIX,1 <---                    RESET INDEX 1
INSEE CLA LOC+1,1 <--                   z
      TMI INDEC+1 ---                   IF z=-1, LEAVE LOOP
      CLA LOC+17,1  |                   Θ
      TSX SIN,4     |
      STO LOC+18,1  |                   sin Θ
      CLA LOC+17,1  |                   Θ
      TSX COS,4     |
      STO LOC+19,1  |                   cos Θ
INDEC TXI INSEE,1---
      REM HYDROSTATIC AND INTERNAL LOAD COMPONENTS
      LXD NIX,3 <---                    RESET INDICES 1 AND 2
      CLA LOC+1,1 <--                   z
      TMI INDED+1 ---                   IF z=-1, LEAVE LOOP
      LDQ LOC+16,1  |                   Hw
      FMP ASIDE+2   |                   b
      STO LOC+16,1  |                   Hw b
      LDQ LOC+16,1  |                   bHw
      FMP INPUT+5   |                   a
      STO LOC+16,1  |                   H = abHw
      LDQ LOC+16,1  |                   H
      FMP LOC+18,1  |                   sin Θ
      STO LOC+15,1  |                   H sin Θ
      LDQ LOC+16,1  |                   H
      FMP LOC+19,1  |                   cos Θ
      FSB LOAD,2    |                   c+w
      STO LOC+16,1  |                   H cos Θ - (c+w)
INDFA TXI INDED,2 ---
                 135 135
                   135
```



$$v_i = H_i \cos\theta_i - (c+w)_i - s_i \sin\theta_i$$

$$h_i = H_i \sin\theta_i + s_i \cos\theta_i$$

$$P_K = P_0 \cos\theta_K + Q_0 \sin\theta_K - \cos\theta_K \sum_{i=0}^{i=K} h_i + \sin\theta_K \sum_{i=0}^{i=K} v_i$$

$$Q_K = -P_0 \sin\theta_K + Q_0 \cos\theta_K + \sin\theta_K \sum_{i=0}^{i=K} h_i + \cos\theta_K \sum_{i=0}^{i=K} v_i$$

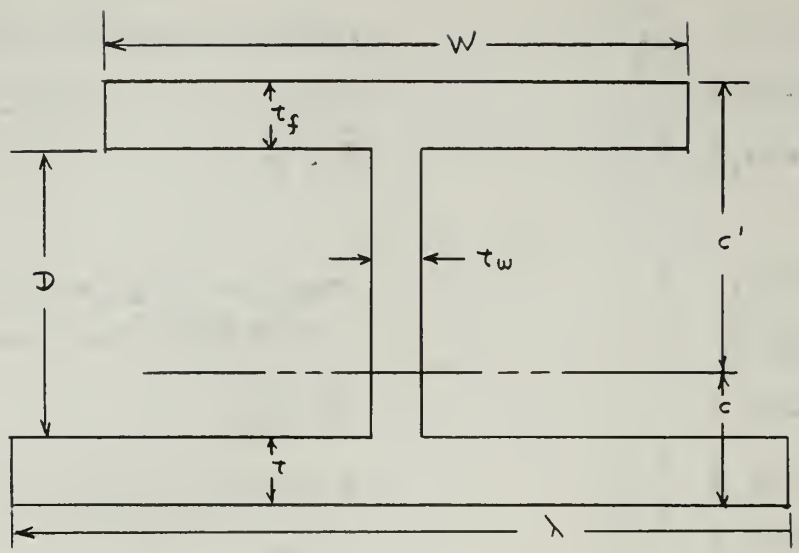
$$M_K = M_0 - P_0 Z_K + Q_0 Y_K + \sum_{i=0}^{i=K} h_i (Z_K - Z_i) + \sum_{i=0}^{i=K} v_i (Y_K - Y_i)$$

```
                    133 | ↑ | 133
INDED TXI INDEC+2,1 ←-|-|-
      LXD NIX,3 ←-----|        RESET INDICES 1 AND 2
      STZ TEMP+4               SET TO ZERO
      STZ TEMP+5               SET TO ZERO
      STZ TEMP+6               SET TO ZERO
      STZ TEMP+7               SET TO ZERO
      REM SUMMATION OF EXTERNAL LOADS
INSEF CLA LOC+1,1 ←-|          Z
      TMI INDEE+1 --|          IF Z=-1, LEAVE LOOP
      CLA LOC+15,1  |          H SIN θ
      FAD TEMP+4    |          Σ H sin θ
      STO TEMP+4    |          Σ H sin θ
      STO LOC+12,1  |          Σ H sin θ
      CLA LOC+16,1  |          H cos θ - (c+ω)
      FAD TEMP+5    |          Σ[H cos θ - (c+ω)]
      STO TEMP+5    |          Σ[H cos θ - (c+ω)]
      STO LOC+13,1  |          Σ[H cos θ - (c+ω)]
INDEE TXI INSEF,1 --|
      REM SHEAR FORCE CALCULATIONS
      LXD NIX,1 ←---|          RESET INDEX 1
      CLA TEMP+5               Σ[H cos θ - (c+ω)] = V
      FDP TEMP+2               I
      FMP ASIDE+2              b
      STO REMEM+4              Vb/I
      CLA LOC+1,1 ←-|          Z
      TMI INDEF+1 --|          IF Z=-1, LEAVE LOOP
      LDQ REMEM+4   |          Vb/I
      FMP LOC+20,1  |          Q_n
                    136 | ↓ | 136
```

```
                                                    135 ↑ | 135
        STO  LOC+20,1                               |     | S_n = bVQ_n / I
        LDQ  LOC+19,1                               |     | cos θ_n
        FMP  LOC+20,1                               |     | S_n
        STO  LOC+21,1                               |     | S_n cos θ_n
        REM  TOTAL EXTERNAL FORCE COMPONENTS        |     |
        FAD  TEMP+7                                 |     | Σ S_n cos θ_n
        STO  TEMP+7                                 |     | Σ S_n cos θ_n
        FAD  LOC+12,1                               |     | Σ H sin θ
        STO  LOC+12,1                               |     | Σ[H sin θ + S cos θ]_n
        CLA  LOC+21,1                               |     | S_n cos θ_n
        FAD  LOC+15,1                               |     | H sin θ
        STO  LOC+15,1                               |     | H sin θ + S cos θ
        LDQ  LOC+18,1                               |     | sin θ
        FMP  LOC+20,1                               |     | S_n
        STO  LOC+20,1                               |     | S_n sin θ_n
        FAD  TEMP+6                                 |     | Σ S_n sin θ_n
        STO  TEMP+6                                 |     | Σ S_n sin θ_n
        CHS                                         |     |
        FAD  LOC+13,1                               |     | Σ [H cos θ - (c+ω)]
        STO  LOC+13,1                               |     | Σ [H cos θ - (c+ω) - S sin θ]
        CLA  LOC+16,1                               |     | H cos θ - (c+ω)
        FSB  LOC+20,1                               |     | S sin θ
        STO  LOC+16,1                               |     | H cos θ - (c+ω) - S sin θ
INDEF   TXI  INDEE+6,1 ←-----------------------------┘     |
        REM  TOTAL EXTERNAL MOMENT COMPONENTS               |
        LXD  NIX,3 ←-------------------------------┐        | RESET INDICES 1 AND 2
INSEG   CLA  LOC+1,1 ←-------------------------┐   |        | Z
        TMI  INDEG+3 ---------------------┐    |   |        | IF Z = -1, LEAVE LOOP
                                          |    |   |
                                137 ↓ | 137 |   |
```

```
136 ↑ | 136
      STZ LOC+3,1          SET TO ZERO
      STZ LOC+4,1          SET TO ZERO
      STZ LOC+5,1          SET TO ZERO
INSEH CLA LOC,2 ←          c_i
      CAS LOC,1            COMPARE c_i WITH c_K
      NOP
      TRA INDEG+1 --       IF c_i ≥ c_K SKIP
      CLA LOC+1,1          z_K
      FSB LOC+1,2          z_i
      STO TEMP             z_K - z_i
      LDQ LOC+15,2         H sinθ + S cosθ
      FMP TEMP             z_K - z_i
      FAD LOC+5,1          Σ[(H sinθ + S cosθ)_i (z_K - z_i)]
      STO LOC+5,1          Σ[(H sinθ + S cosθ)(z_K - z)]_i
      CLA LOC+2,1          Y_K
      FSB LOC+2,2          Y_i
      STO TEMP             Y_K - Y_i
      LDQ LOC+16,1         H cosθ - (c+ω) - S sinθ
      FMP TEMP             Y_K - Y_i
      FAD LOC+5,1          Σ[(H cosθ - (c+ω) - S sinθ)(Y_K - Y)]_i
                           + Σ[(H sinθ + S cosθ)(z_K - z)]_i = M_ex
      STO LOC+5,1          Σ[(H cosθ - (c+ω) - S sinθ)(Y_K - Y)]_i
      STO LOC+24,1         + Σ[(H sinθ + S cosθ)(z_K - z)]_i = M_ex
                           M = M_ex
INDEG TXI INSEH,2 --
      LXD NIX,2 ← ---      RESET INDEX 2
INDEH TXI INSEG,1 --
      LXD NIX,1 ← ----     RESET INDEX 1
      CLA LOC+1,1 ←        z
      TMI INDEI+1 --       IF Z = -1, LEAVE LOOP
138 | ↓ 138
```

```
      LDQ  LOC+13,1      Σ[H cos θ - (c+ω) - S sin θ]
      FMP  LOC+18,1      sin θ
      STO  LOC+3,1       sin θ Σ[H cos θ - (c+ω) - S sin θ]
      LDQ  LOC+12,1      Σ[H sin θ + S cos θ]
      FMP  LOC+19,1      cos θ
      CHS
      FAD  LOC+3,1       Pex = cos θ Σ[H sin θ + S cos θ]
      STO  LOC+3,1         - sin θ Σ[H cos θ - (c+ω) - S sin θ]
      STO  LOC+22,1      P = Pex
      LDQ  LOC+13,1      Σ[H cos θ - (c+ω) - S sin θ]
      FMP  LOC+19,1      cos θ
      STO  LOC+4,1       cos θ Σ[H cos θ - (c+ω) - S sin θ]
      LDQ  LOC+12,1      Σ[H sin θ + S cos θ]
      FMP  LOC+18,1      sin θ
      FAD  LOC+4,1       Qex = sin θ Σ[H sin θ + S cos θ]
      STO  LOC+4,1          + cos θ Σ[H cos θ - (c+ω) - S sin θ]
      STO  LOC+23,1      Q = Qex
INDEI TXI  INDEH+2,1
      STZ  REMEM+11      SET TO ZERO
      STZ  REMEM+12      SET TO ZERO
      STZ  REMEM+13      SET TO ZERO
      STZ  REMEM+14      SET TO ZERO
      LXD  NIX,3         RESET INDICES 1 AND 2
      REM SIZING WEB DIMENSIONS
INSEI CLA  PLATE+1,2     t
      TMI  EXIT,4        IF t = -1  LEAVE PROGRAM
      LDQ  PLATE+1,2     t
      STQ  TEMP          τ = τω
```



CRITERIA FOR SIZING COMPONENTS OF WEB FRAME

$t_f = 1.5\, t_w$

$10\tau_w \leq W \leq 30 t_w \qquad W \leq 2D$

$D \leq 60 t_w \qquad \lambda = 30t$

$$A = (\lambda - t_w)t + (D + t_f + \tau)t_w + (W - t_w)t_f$$

$$Q = (\lambda - t_w)\frac{t^2}{2} + (D + t_f + \tau)^2\frac{t_w}{2} + (W - t_w)t_f\left(D + \tau + \frac{t_f}{2}\right)$$

$$I_o = (\lambda - t_w)\frac{t^3}{3} + (D + t_f + \tau)^3\frac{t_w}{3} + (W - t_w)t_f\left[\left(D + \tau + \frac{t_f}{2}\right)^2 + \frac{t_f^2}{12}\right]$$

$$c = \frac{Q}{A}$$

$$c' = (D + t + t_f) - c$$

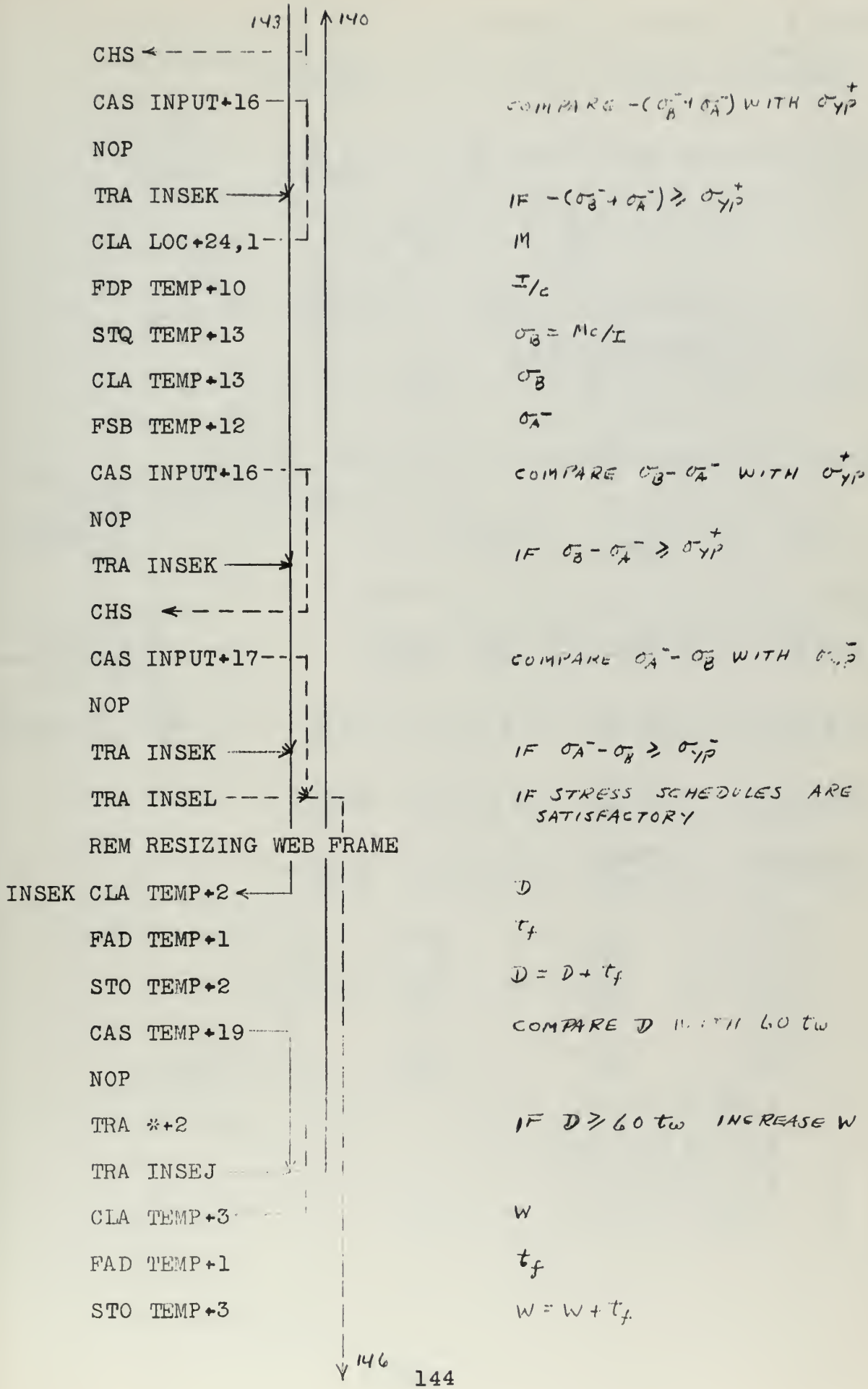
```
      FMP CONST+26                    1.5
      STO TEMP+1                      t_f = 1.5 t_ω
      LDQ PLATE+1,2                   t_ω
      FMP CONST+17                    30
      STO TEMP+18                     30 t_ω
      FDP CONST+14                    0.5
      STQ TEMP+19                     60 t_ω
      LDQ PLATE+1,2                   t_ω
      FMP CONST+31                    5
      STO TEMP+2                      D ≥ 5 t_ω
      FDP CONST+14                    0.50
      STQ TEMP+3                      W ≤ 2D ≥ 10 t_ω
      REM CALC OF AREA AND MOM OF INERTIA OF WEB
INSEJ LDQ LOC+7,1                     t
      FMP CONST+17                    30   λ = 30 t
      FSB PLATE+1,2                   t_ω
      STO TEMP+4                      λ - t_ω
      LDQ TEMP+4                      λ - t_ω
      FMP LOC+7,1                     t
      STO TEMP+5                      (λ - t_ω) t
      LDQ TEMP+5                      (λ - t_ω) t
      FMP LOC+7,1                     t
      FDP CONST+2                     2
      STQ TEMP+6                      (λ - t_ω) t²/2
      FMP LOC+7,1                     t
      FDP CONST+26                    1.5
      STQ TEMP+7                      (λ - t_ω) t³/3
      CLA TEMP+2                      D
```

144
146
148

FAD LOC+7,1	t
FAD TEMP+1	t_f
STO TEMP+4	$D+\tau+t_f$
LDQ TEMP	t_ω
FMP TEMP+4	$(D+\tau+t_f)$
STO TEMP+4	$(D+\tau+t_f)t_\omega$
FAD TEMP+5	$(\lambda-t_\omega)\tau$
STO TEMP+5	$(\lambda-t_\omega)t+(D+\tau+t_f)t_\omega$
CLA TEMP+4	$(D+\tau+t_f)t_\omega$
FDP CONST+2	2
FMP TEMP+4	$(D+\tau+t_f)t_\omega$
FDP TEMP	t_ω
STQ TEMP+4	$(D+\tau+t_f)^2 t_\omega/2$
CLA TEMP+4	
FAD TEMP+6	$(\lambda-t_\omega)\tau^2/2$
STO TEMP+6	$(\lambda-t_\omega)\tau^2/2+(D+\tau+t_f)^2\frac{t_\omega}{2}$
CLA TEMP+4	$(D+\tau+t_f)t_\omega/2$
FDP CONST+26	1.5
FMP TEMP+4 (FDP TEMP t_ω)	$(D+\tau+t_f)t_\omega$
FAD TEMP+7 (STQ TEMP+4, CLA TEMP+4)	$(\lambda-t_\omega)\frac{\tau^3}{3}$
STO TEMP+7	$(\lambda-t_\omega)\frac{\tau^3}{3}+(D+\tau+t_f)^3\frac{t_\omega}{3}$
CLA TEMP+3	W
FSB TEMP	t_ω
STO TEMP+4	$W-t_\omega$
LDQ TEMP+4	$W-t_\omega$
FMP TEMP+1	t_f
STO TEMP+4	$(W-t_\omega)t_f$
FAD TEMP+5	$(\lambda-t_\omega)t+(D+\tau+t_f)t_\omega$
STO TEMP+5	$A=(\lambda-t_\omega)t+(D+\tau+t_f)t_\omega+$ $+(W-t_\omega)t_f$
CLA TEMP+1	t_f

FDP CONST+2	2
STQ TEMP+8	$\tau_{f/2}$
CLA TEMP+8	$\tau_{f/2}$
FAD LOC+7,1	τ
FAD TEMP+2	D
STO TEMP+8	$D+\tau+\frac{\tau_f}{2}$
LDQ TEMP+4	$(W-\tau_\omega)t_f$
FMP TEMP+8	$D+\tau+\tau_{f/2}$
FAD TEMP+6	$Q=(\lambda-\tau_\omega)t_{/2}^2+(D+\tau+\tau_f)^2\frac{\tau_\omega}{2}+$
STO TEMP+6	$+(W-\tau_\omega)t_f\left(D+\tau+\frac{\tau_f}{2}\right)$
LDQ TEMP+8	$D+\tau+\tau_{f/2}$
FMP TEMP+8	$D+\tau+\tau_{f/2}$
STO TEMP+8	$(D+\tau+\tau_{f/2})^2$
CLA TEMP+1	τ_f
FDP CONST+5	12
FMP TEMP+1	t_f
FAD TEMP+8	$(D+\tau+t_{f/2})^2$
STO TEMP+8	$t_{f/2}^2+(D+\tau+\tau_{f/2})^2$
LDQ TEMP+4	$(W-\tau_\omega)t_f$
FMP TEMP+8	$t_{f/2}^2+(D+\tau+\tau_{f/2})^2$
FAD TEMP+7	$I_0=(\lambda-\tau_\omega)\frac{\tau_\omega^3}{3}+(D+\tau+\tau_f)\frac{\tau_\omega^3}{3}+$
STO TEMP+7	$+(W-\tau_\omega)\tau_f\left[t_{f/2}^2+\left(D+\tau+\frac{\tau_f}{2}\right)^2\right]$
CLA TEMP+6	Q
FDP TEMP+5	A
STQ TEMP+8	$c=Q/A$
CLA TEMP+2	D
FAD TEMP+1	t_f
FAD LOC+7,1	t

```
FSB TEMP+8                          c
STO TEMP+9                          c'
LDQ TEMP+8                          c
FMP TEMP+8                          c
STO TEMP+10                         c^2
LDQ TEMP+10                         c^2
FMP TEMP+5                          A
SSM
FAD TEMP+7                          I_o
STO TEMP+7                          I = I_o - Ac^2
REM CALCULATION OF SECTION MODULI
FDP TEMP+8                          c
STQ TEMP+10                         I/c
CLA TEMP+7                          I'
FDP TEMP+9                          c'
STQ TEMP+11                         I/c'
REM STRESS SCHEDULES
CLA LOC+22,1                        P (POSITIVE IN COMPRESSION)
FDP TEMP+5                          A
STQ TEMP+12                         σ_A^- = P/A
CLA LOC+24,1                        M
FDP TEMP+11                         I/c'
STQ TEMP+13                         σ_B^- = Mc'/I
CLA TEMP+13                         σ_B^-
FAD TEMP+12                         σ_A^-
CAS INPUT+17 ---+                   COMPARE σ_A^- + σ_B^- WITH σ_yp^-
NOP             :
TRA INSEK ------:                   IF σ_A^- + σ_B^- ≥ σ_yp^-
                :
144 ↓           ↓ 144
```


143
140
CHS
CAS INPUT+16
NOP
TRA INSEK
CLA LOC+24,1
FDP TEMP+10
STQ TEMP+13
CLA TEMP+13
FSB TEMP+12
CAS INPUT+16
NOP
TRA INSEK
CHS
CAS INPUT+17
NOP
TRA INSEK
TRA INSEL
REM RESIZING WEB FRAME
INSEK CLA TEMP+2
FAD TEMP+1
STO TEMP+2
CAS TEMP+19
NOP
TRA *+2
TRA INSEJ
CLA TEMP+3
FAD TEMP+1
STO TEMP+3
146
COMPARE $-(\sigma_B^- + \sigma_A^-)$ WITH σ_{yp}^+
IF $-(\sigma_B^- + \sigma_A^-) \geq \sigma_{yp}^+$
M
I/c
$\sigma_B = Mc/I$
σ_B
σ_A^-
COMPARE $\sigma_B - \sigma_A^-$ WITH σ_{yp}^+
IF $\sigma_B - \sigma_A^- \geq \sigma_{yp}^+$
COMPARE $\sigma_A^- - \sigma_B$ WITH σ_{yp}^-
IF $\sigma_A^- - \sigma_B \geq \sigma_{yp}^-$
IF STRESS SCHEDULES ARE SATISFACTORY
D
t_f
$D = D + t_f$
COMPARE D WITH 60 t_w
IF $D \geq 60\ t_w$ INCREASE W
W
t_f
$W = W + t_f$

GENERAL EQUILIBRIUM EQUATIONS

ASSUME 2 SYMMETRICALLY SPACED STANCHIONS PROVIDING 4 REDUNDANT FORCE R_0 (POSITIVE IN COMPRESSION)

$$P_K = P_0 \cos\theta_K + Q_0 \sin\theta_K - \cos\theta_K \sum_{i=0}^{i=K} h_i + \sin\theta_K \sum_{i=0}^{i=K} v_i - R_0 \sin\theta_K \quad (Y_K > Y_R)$$

$$= P_0 \cos\theta_K + Q_0 \sin\theta_K + P_{EX} - R_0 \sin\theta_K$$

WHERE $P_{EX} = -\cos\theta_K \sum_{i=0}^{i=K} h_i + \sin\theta_K \sum_{i=0}^{i=K} v_i$

$$Q_K = -P_0 \sin\theta_K + Q_0 \cos\theta_K + \sin\theta_K \sum_{i=0}^{i=K} h_i + \cos\theta_K \sum_{i=0}^{i=K} v_i + R_0 \cos\theta_K \quad (Y_K > Y_R)$$

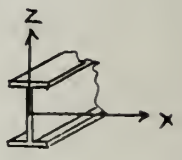
$$= -P_0 \sin\theta_K + Q_0 \cos\theta_K + Q_{EX} + R_0 \cos\theta_K$$

WHERE $Q_{EX} = \sin\theta_K \sum_{i=0}^{i=K} h_i + \cos\theta_K \sum_{i=0}^{i=K} v_i$

$$M_K = M_0 - P_0 z_K + Q_0 Y_K + \sum_{i=0}^{i=K} h_i (z_K - z_i) + \sum_{i=0}^{i=K} v_i (Y_K - Y_i) - R_0 (Y_K - Y_R) \quad (Y_K > Y_R)$$

$$= M_0 - P_0 z_K + Q_0 Y_K + M_{EX} - R_0 (Y_K - Y_2)$$

WHERE $M_{EX} = \sum_{i=0}^{i=K} h_i (z_K - z_i) + \sum_{i=0}^{i=K} v_i (Y_K - Y_i)$



ASSUME STANCHION TO BE PIN CONNECTED

INTERNAL ENERGY STORED IN WEB UNDER LOAD:

$$U = \frac{1}{2E}\oint \frac{P_K^2}{A_K} dl + \frac{1}{2G}\oint \frac{\mu Q_K^2}{A_K} dl + \frac{1}{2E}\int \frac{M_K^2}{I_K} dl + \frac{R_0^2 L}{2AE}$$

$$\mu = \frac{\iint \tau^2 dz\, dx}{\left[\iint \tau\, dz\, dx\right]^2}$$

$$\tau = \frac{VQ}{tI} = \frac{V}{tI}\iint z\, dz\, dx$$

$$\frac{dU}{dP_0} = \frac{1}{E}\oint \frac{P_K}{A_K}\frac{dP_K}{dP_0} dl + \frac{1}{G}\oint \frac{\mu Q}{A_K}\frac{dQ}{dP_0} dl + \frac{1}{E}\oint \frac{M_K}{I_K}\frac{dM_K}{dP_0} dl + \frac{R_0 L}{AE}\frac{dR_0}{dP_0} = 0$$

$$\frac{dU}{dQ_0} = \frac{1}{E}\oint \frac{P_K}{A_K}\frac{dP_K}{dQ_0} dl + \frac{1}{G}\oint \frac{\mu Q_K}{A_K}\frac{dQ_K}{dQ_0} dl + \frac{1}{E}\oint \frac{M_K}{I_K}\frac{dM_K}{dQ_0} dl + \frac{R_0 L}{AE}\frac{dR_0}{dQ_0} = 0$$

$$\frac{dU}{dM_0} = \frac{1}{E}\oint \frac{P_K}{A_K}\frac{dP_K}{dM_0} dl + \frac{1}{G}\oint \frac{\mu Q_K}{A_K}\frac{dQ_K}{dM_0} dl + \frac{1}{E}\oint \frac{M_K}{I_K}\frac{dM_K}{dM_0} dl + \frac{R_0 L}{AE}\frac{dR_0}{dM_0} = 0$$

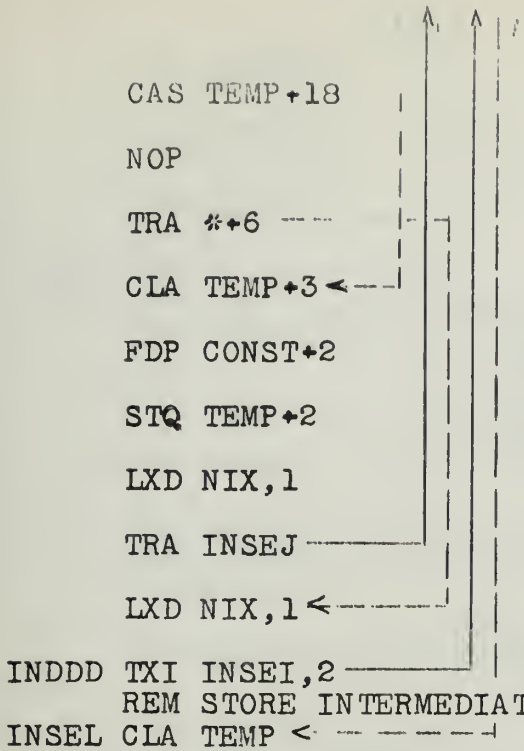
$\frac{dP_K}{dP_0} = \cos\theta$	$\frac{dQ_K}{dP_0} = -\sin\theta$	$\frac{dM_K}{dP_0} = -z_K$	$\frac{dR_0}{dP_0} = \cot\theta$
$\frac{dP_K}{dQ_0} = \sin\theta$	$\frac{dQ_K}{dQ_0} = \cos\theta$	$\frac{dM_K}{dQ_0} = -Y_K$	$\frac{dR_0}{dQ_0} = 1$
$\frac{dP_K}{dM_0} = 0$	$\frac{dQ_K}{dM_0} = 0$	$\frac{dM_K}{dM_0} = 1$	$\frac{dR_0}{dM_0} = \frac{1}{(Y_K - Y_R)}$

$Y \le \frac{B}{2} - R$: $dl = dY$

$\frac{B}{2} - R \le Y \le \frac{B}{2}$: $dl = R\,d\theta$

$R < z < D$: $dl = dz$

$z = D$: $dl = dY$



```
        CAS TEMP+18
        NOP
        TRA *+6
        CLA TEMP+3
        FDP CONST+2
        STQ TEMP+2
        LXD NIX,1
        TRA INSEJ
        LXD NIX,1
INDDD   TXI INSEI,2
        REM STORE INTERMEDIATE DATA
INSEL   CLA TEMP
        STO LOC+6,1
        CLA TEMP+1
        STO LOC+7,1
        CLA TEMP+2
        STO LOC+8,1
        CLA TEMP+3
        STO LOC+9,1
        CLA TEMP+5
        STO LOC+10,1
        CLA TEMP+6
        STO LOC+11,1
        CLA TEMP+7
        STO LOC+12,1
        CLA TEMP+8
        STO LOC+13,1
        CLA TEMP+9
        STO LOC+14,1
```

COMPARE t_ω WITH 30 t_w

IF $t_\omega \geq 30\ t_w$ INCREASE t_w

W

2

$D \geq W/2$

RESET INDEX 1

W = CONST OVER WEB FRAME

RESET INDEX 1

t_w = CONST OVER WEB FRAME

t_ω

t_ω

τ_f

τ_f

D

D

W

W

A

A

Q

Q

I

I

c

c

c'

c'

THE FOLLOWING ASSUMPTIONS WERE MADE FOR THIS PROGRAM

1. NO STANCHIONS ; $R_0 = 0$
2. SYMMETRICAL LOADING ABOUT CENTERLINE ; $Q_0 = 0$
3. SHEAR STRESSES AND STRAINS IGNORED $Q \approx 0$

THE EQUILIBRIUM EQUATIONS ON THE PRECEDING PAGE BECOME:

$$P_K = P_0 \cos\theta_K + P_{EX} \qquad \frac{dP_K}{dP_0} = \cos\theta_K \qquad \frac{dP_K}{dM_0} = 0$$

$$M_K = M_0 - P_0 z_K + M_{EX} \qquad \frac{dM}{dP_0} = -z_K \qquad \frac{dM}{dM_0} = 1$$

INTERNAL ENERGY EQUATIONS BECOME:

$$\frac{dU}{dP_0} = \frac{1}{E}\oint \frac{P_K}{A_K}\frac{dP_K}{dP_0}dl + \frac{1}{E}\oint \frac{M_K}{I_K}\frac{dM_K}{dP_0}dl = 0$$

$$\oint \left(\frac{P_0\cos\theta_K + P_{EX}}{A_K}\right)(\cos\theta_K)dl - \oint\left(\frac{M_0 - P_0 z_K + M_{EX}}{I_K}\right)(z_K)dl = 0$$

$$P_0\oint\left(\frac{\cos^2\theta_K}{A_K} + \frac{z_K^2}{I_K}\right)dl - M_0\oint\left(\frac{z_K}{I_K}\right)dl + \oint\left(\frac{P_{EX}\cos\theta_K}{A_K} - \frac{M_{EX}z_K}{I_K}\right)dl = 0$$

$$\frac{dU}{dM_0} = \frac{1}{E}\oint \frac{P_K}{A_K}\frac{dP_K}{dP_0}dl + \frac{1}{E}\oint \frac{M_K}{I_K}\frac{dM_K}{dP_0}dl = 0$$

$$\oint\left(\frac{M_0 - P_0 z_K + M_{EX}}{I_K}\right)dl = 0$$

$$-P_0\oint\left(\frac{z_K}{I_K}\right)dl + M_0\int\left(\frac{1}{I_K}\right)dl + \int\left(\frac{M_{EX}}{I_K}\right)dl = 0$$

THE INTEGRATIONS ARE APPROXIMATED BY SUMMATIONS:

$dl = b$

$$P_0\sum_{K=0}^{K=n}\left(\frac{\cos^2\theta_K}{A_K} + \frac{z_K^2}{I_K}\right) + M_0\sum_{K=0}^{K=n}-\left(\frac{z_K}{I_K}\right) + \sum_{K=0}^{K=n}\left(\frac{P_{EX}\cos\theta_K}{A_K} - \frac{M_{EX}z_K}{I_K}\right) = 0$$

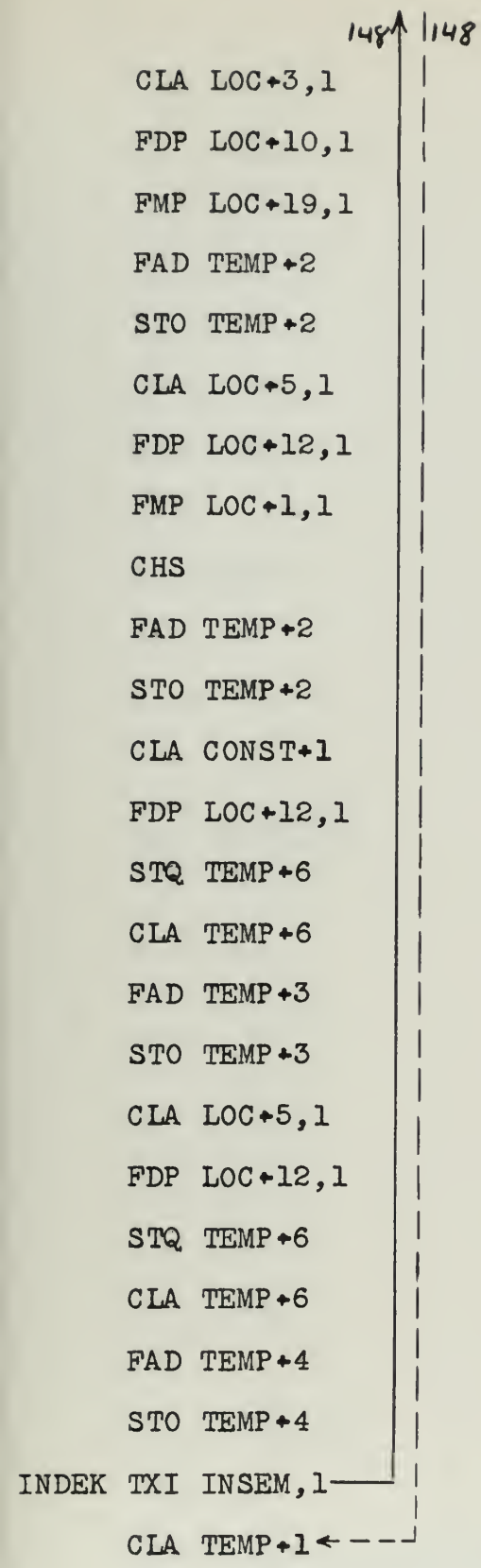
$$P_0\sum_{K=0}^{K=n}-\left(\frac{z_K}{I_K}\right) + M_0\sum_{K=0}^{K=n}\left(\frac{1}{I_K}\right) + \sum_{K=0}^{K=n}\left(\frac{M_{EX}}{I_K}\right) = 0$$

FROM WHICH:

$$P_0 = -\frac{\left[\sum_{K=0}^{K=n}\left(\frac{z_K}{I_K}\right)\right]\left[\sum_{K=0}^{K=n}\left(\frac{M_{EX}}{I_K}\right)\right] + \left[\sum_{K=0}^{K=n}\left(\frac{P_{EX}\cos\theta_K}{A_K} - \frac{M_{EX}z_K}{I_K}\right)\right]\left[\sum_{K=0}^{K=n}\left(\frac{1}{I_K}\right)\right]}{\left[\sum_{K=0}^{K=n}\left(\frac{\cos^2\theta_K}{A_K} + \frac{z_K^2}{I_K}\right)\right]\left[\sum_{K=0}^{K=n}\left(\frac{1}{I_K}\right)\right] - \left[\sum_{K=0}^{K=n}\left(\frac{z_K}{I_K}\right)\right]^2}$$

$$M_0 = \frac{\left[\sum_{K=0}^{K=n}\left(\frac{z_K}{I_K}\right)\right]P_0 - \left[\sum_{K=0}^{K=n}\left(\frac{M_{EX}}{I_K}\right)\right]}{\left[\sum_{K=0}^{K=n}\left(\frac{1}{I_K}\right)\right]}$$

```
                                                  140
        CLA  TEMP+3                               W
        FDP  CONST+2                              2
        STQ  TEMP+2                               D = W/2
INDEJ   TXI  *+1,1                                
        CLA  LOC+1,1                              Z
        TMI  *+2                                  IF Z=-1, LEAVE LOOP
        TRA  INSEJ
        LXD  NIX,3                                RESET INDICES 1 AND 2
REM CALC OF REDUNDANT FORCES
        STZ  TEMP                                 SET TO ZERO
        STZ  TEMP+1                               SET TO ZERO
        STZ  TEMP+2                               SET TO ZERO
        STZ  TEMP+3                               SET TO ZERO
INSEM   CLA  LOC+1,1                              Z
        TMI  INDEK+1                              IF Z=-1, LEAVG LOOP
        CLA  LOC+19,1                             cos θ
        FDP  LOC+10,1                             A
        FMP  LOC+19,1                             cos θ
        FAD  TEMP                                 Σ cos²θ/A
        STO  TEMP                                 Σ cos²θ/A
        CLA  LOC+1,1                              Z
        FDP  LOC+12,1                             I
        STQ  TEMP+6                               Z/I
        FMP  LOC+1,1                              Z
        FAD  TEMP                                 Σ cos²θ/A
        STO  TEMP                                 Σ [Z²/I + cos²θ/A]
        CLA  TEMP+6                               Z/I
        FAD  TEMP+1                               Σ Z/I
        STO  TEMP+1                               Σ Z/I
                                                  149
                                                  149
```



P_{Ex}

A

$\cos\theta$

$\Sigma \frac{P_{Ex}\cos\theta}{A}$

$\Sigma \frac{P_{Ex}\cos\theta}{A}$

M_{Ex}

I

z

$\Sigma \frac{P_{Ex}\cos\theta}{A}$

$\Sigma\left[\frac{P_{Ex}\cos\theta}{A} - \frac{M_{Ex}z}{I}\right]$

1.0

I

$1/I$

$1/I$

$\Sigma\ 1/I$

$\Sigma\ 1/I$

M_{Ex}

I

M_{Ex}/I

M_{Ex}/I

$\Sigma\ M_{Ex}/I$

$\Sigma\ M_{Ex}/I$

$\Sigma\ z/I$

$-\Sigma\ z/I$

$\Sigma \frac{M_{Ex}}{I}$

```
FDP TEMP+3
FMP TEMP+1
FSB TEMP+2
STO TEMP+6
CLA TEMP+1
FDP TEMP+3
FMP TEMP+1
CHS
FAD TEMP
STO TEMP+7
CLA TEMP+6
FDP TEMP+7
STQ REMEM+11
CLA REMEM+11
FDP TEMP+3
FMP TEMP+1
STO TEMP+6
CLA TEMP+4
FDP TEMP+3
STQ TEMP+7
CLA TEMP+7
FAD TEMP+6
CHS
STO REMEM+12
TSX R,4
PZE REMEM+11,0,REMEM+12
REM ACCURACY TEST FOR REDUNDANT FORCES
CLA REMEM+11
FSB REMEM+13
FDP REMEM+11
```

$\Sigma\ 1/I$

$-\Sigma\ z/I$

$\Sigma\left[\frac{P_{Ex}\cos\theta}{A} - \frac{M_{Ex}z}{I}\right]$

$\left(\Sigma\frac{M_{Ex}}{I}\right)\left(-\Sigma\frac{z}{I}\right)\left(\Sigma\ 1/I\right)^{-1} - \Sigma\left[\frac{P_{Ex}\cos\theta}{A} - \frac{M_{Ex}z}{I}\right]$

$-\Sigma\ z/I$

$\Sigma\ 1/I$

$-\Sigma\ z/I$

$\Sigma\ \cos^2\theta/A$

$\Sigma\cos^2\theta/A - \left(-\Sigma\ z/I\right)^2\left(\Sigma\ 1/I\right)^{-1}$

$\left(\Sigma\frac{M_{Ex}}{I}\right)\left(-\Sigma\frac{z}{I}\right)\left(\Sigma\frac{1}{I}\right)^{-1} - \Sigma\left[\frac{P_{Ex}\cos\theta}{A} - \frac{M_{Ex}z}{I}\right]$

$\Sigma\cos^2\theta/A - \left(-\Sigma\ z/I\right)^2\left(\Sigma\ 1/I\right)^{-1}$

P_0

P_0

$\Sigma\ 1/I$

$-\Sigma\ z/I$

$P_0\left(-\Sigma\ z/I\right)\left(\Sigma\ 1/I\right)^{-1}$

$\Sigma\ M_{Ex}/I$

$\Sigma\ 1/I$

$\left(\Sigma\ M_{Ex}/I\right)\left(\Sigma\ 1/I\right)^{-1}$

$\left(\Sigma\ M_{Ex}/I\right)\left(\Sigma\ 1/I\right)^{-1}$

$P_0\left(-\Sigma\ z/I\right)\left(\Sigma\ 1/I\right)^{-1}$

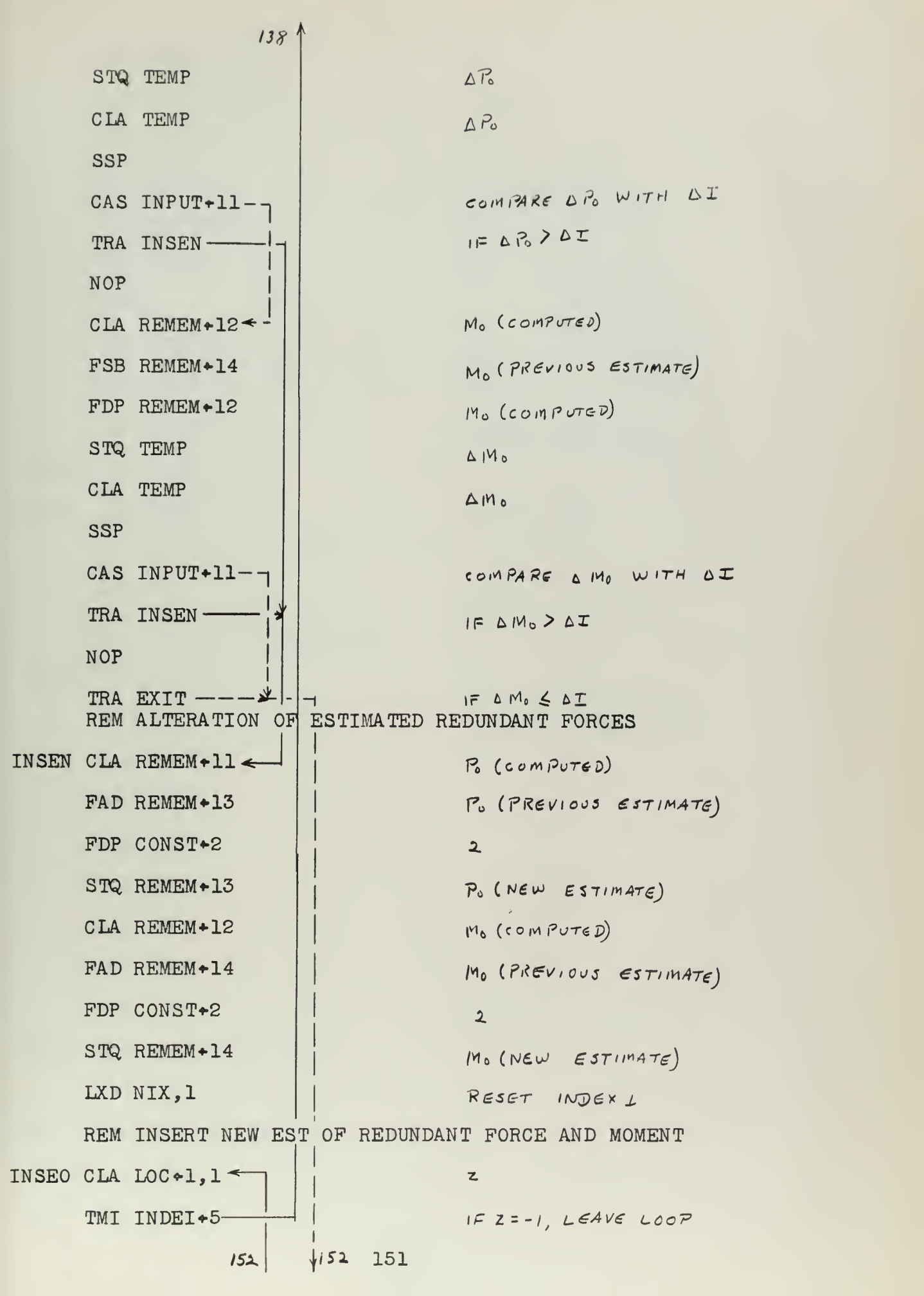
$M_0 = \left(\Sigma\ M_{Ex}/I\right)\left(\Sigma\ 1/I\right)^{-1} + P_0\left(-\Sigma\ z/I\right)\left(\Sigma\frac{1}{I}\right)^{-1}$

PRINT OUT P_0, M_0

P_0 (COMPUTED)

P_0 (PREVIOUS ESTIMATE)

P_0 (COMPUTED)


138
STQ TEMP
ΔP₀
CLA TEMP
ΔP₀
SSP
CAS INPUT+11
COMPARE ΔP₀ WITH ΔI
TRA INSEN
IF ΔP₀ > ΔI
NOP
CLA REMEM+12
M₀ (COMPUTED)
FSB REMEM+14
M₀ (PREVIOUS ESTIMATE)
FDP REMEM+12
M₀ (COMPUTED)
STQ TEMP
ΔM₀
CLA TEMP
ΔM₀
SSP
CAS INPUT+11
COMPARE ΔM₀ WITH ΔI
TRA INSEN
IF ΔM₀ > ΔI
NOP
TRA EXIT
IF ΔM₀ ≤ ΔI
REM ALTERATION OF ESTIMATED REDUNDANT FORCES
INSEN CLA REMEM+11
P₀ (COMPUTED)
FAD REMEM+13
P₀ (PREVIOUS ESTIMATE)
FDP CONST+2
2
STQ REMEM+13
P₀ (NEW ESTIMATE)
CLA REMEM+12
M₀ (COMPUTED)
FAD REMEM+14
M₀ (PREVIOUS ESTIMATE)
FDP CONST+2
2
STQ REMEM+14
M₀ (NEW ESTIMATE)
LXD NIX,1
RESET INDEX 1
REM INSERT NEW EST OF REDUNDANT FORCE AND MOMENT
INSEO CLA LOC+1,1
Z
TMI INDEI+5
IF Z=-1, LEAVE LOOP
152
152 151

```
                151 ↑ |151
      LDQ REMEM+13  |        P₀
      FMP LOC+19,1  |        cos θ
      FAD LOC+3,1   |        P_ex
      STO LOC+22,1  |        P = P_ex + P₀ cos θ
      LDQ REMEM+13  |        P₀
      FMP LOC+1,1   |        z
      CHS           |
      FAD REMEM+14  |        M₀
      FAD LOC+5,1   |        M_ex
      STO LOC+24,1  |        M = M_ex + M₀ - P_ex z
INDEL TXI INSE0,1 ——|
EXIT  LXD NIX,1 ←———|        RESET INDEX 1
      REM PRINT OUT ANSWERS
      TSX R,4                PRINT OUT P₀, M₀
      PZE REMEM+11,0,REMEM+12
INSEP CLA LOC+1,1 ←———————   z
      TMI END ————————————   IF z=-1, LEAVE LOOP
      CAL CRANK       |
      ACL FIVE        |
      SLW FIVE        |
      CAL CRANK       |
      ACL SIX         |
      SLW SIX         |
      TSX N,4         |      PRINT OUT C, z, Y
FIVE  PZE LOC-50,0,LOC-48
      TSX S,4         |      PRINT OUT T_w, T_f, D, W
SIX   PZE LOC-44,0,LOC-41
INDEM TXI INSEP,1 ————|
END   HLT ←———————————|
```

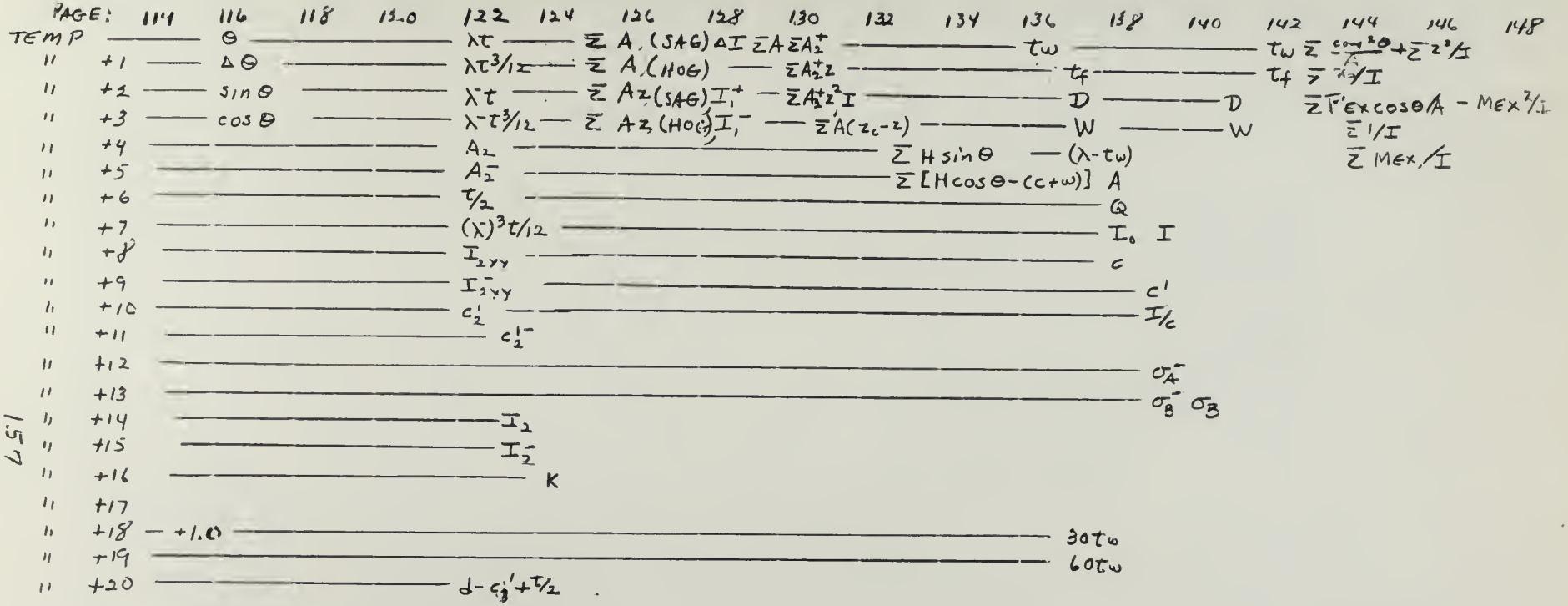
```
L       TRA BLOCK
        BCD 76H AREA=E15.8,6H    N=F6.1,6H    A=F6.1
M       TRA BLOCK
        BCD 812H INERTIA PL=E15.8,16H    INERTIA MIN=E15.8
N       TRA BLOCK
        BCD 810H LOCATION=F6.1,6H    Z=F6.1,6H    Y=F6.1
O       TRA BLOCK
        BCD 627H LENGTH/RADIUS OF GYRATION=F6.1
P       TRA BLOCK
        BCD 918H LOCATION=F6.1,4H  Z=F6.1,4H  Y=F6.1,5H  WT=F6.1
Q       TRA BLOCK
        BCD 918H NEUTRAL AXIS SAG=F6.1,19H  NEUTRAL AXIS HOG=F6.1
R       TRA BLOCK
        BCD 67H    PO=E15.8,7H    MO=E15.8
S       TRA BLOCK
        BCD 95H  TW=F6.1,5H  TF=F6.1,4H  D=F6.1,4H  W=F6.1
INPUT   BSS 30
LOAD    BSS 100
ASIDE   BSS 15
REMEM   BSS 15
LOC     BSS 5000
CONST   DEC -1.0,1.0,2.0,0.29289,-0.4292
        DEC 12.0,40000.,1.70,7.7855,-0.04
        DEC 0.29767,-0.02171546,1.5708,0.8660,0.50
        DEC 10414.,0.0127,30.,18.,324.0
        DEC 54.,9.6,-1.6,-0.88,16970.6,20.,1.5
        DEC 0.90,1.10,2240.0,144.0,5.0,0.0,0.0,0.0,0.0,0.0
TEMP    BSS 40
```

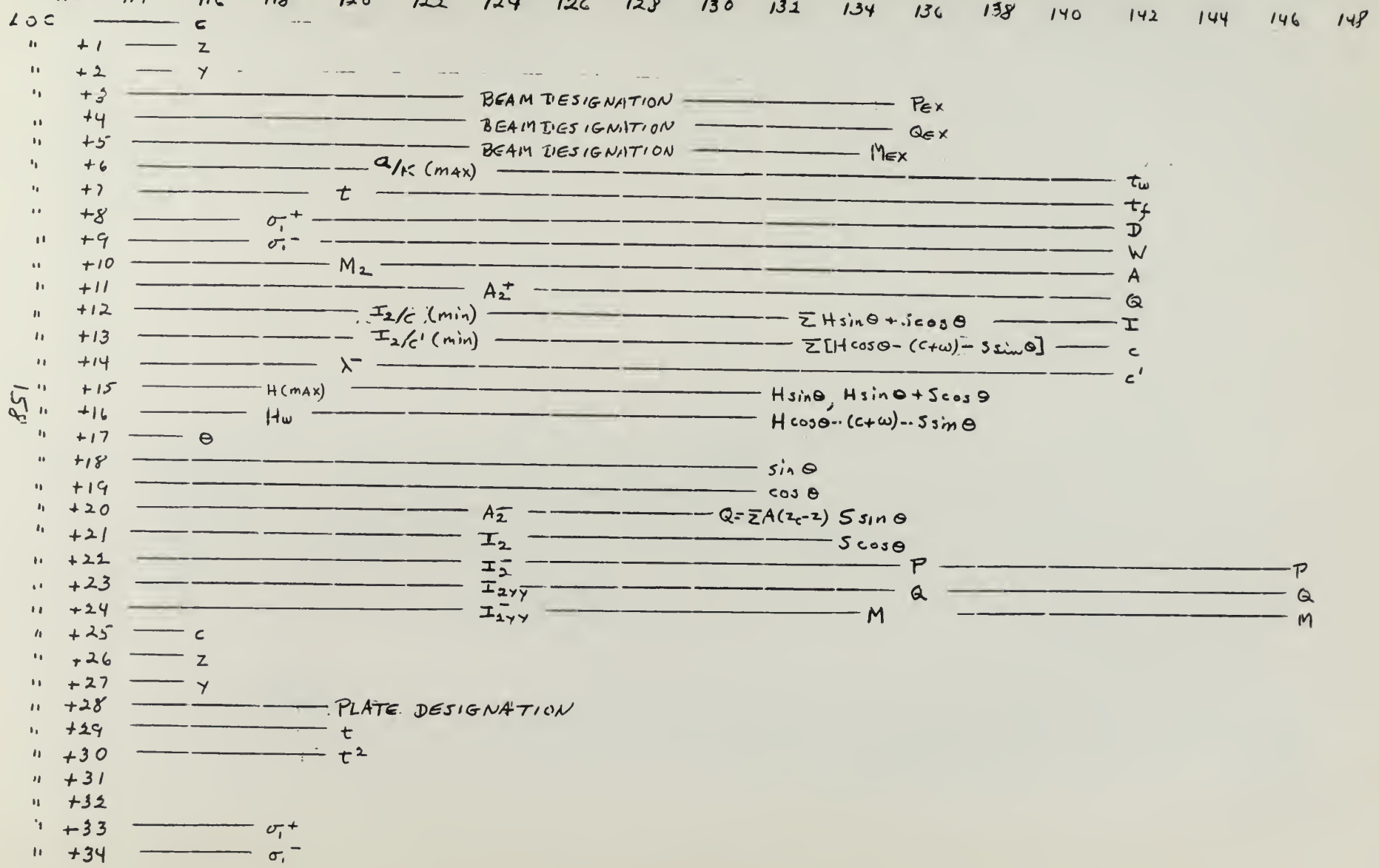
```
NIX    PZE
CRANK  PZE 50,0,50
HANDL  PZE 0,0,24
       PZE 0,0,49
       PZE 0,0,9
       PZE 0,0,2
00008  TRA INSDF                    ESCAPE FROM (AC) UNDERFLOW
INSDF  SXD TEMP+17,1
       LXD 0,1
       TNX INSDG,1,4
       CAL 0
       HTR
INSDG  CAL 0
       STA INSDH
       PXD 0,0
       LXD TEMP+17,1
INSDH  TRA 0
       END START
       CST M885-721-PROGRAM
       REM INPUT INFORMATION FOR PROGRAM M885
       SAP M885-721-INPUT
       LST OFF
       ORG INPUT
       DEC    .          (FT)  DEPTH
       DEC    .          (FT)  BEAM
       DEC               (FT)  BILGE RADIUS
       DEC    .          (FT)  FULL LOAD DRAFT
       DEC    .          (FT)  WAVE CREST HEIGHT ABOVE KEEL
```

```
DEC    .          (IN)    INITIAL FRAME SPACING
DEC    .          (IN)    INCREMENT OF FRAME SPACING
DEC    .          (IN)    FINAL FRAME SPACING
DEC    .                  INITIAL NUMBER OF LONGITUDINALS
DEC    .                  INCREMENT OF NUMBER OF LONGITUDINALS
DEC    .                  FINAL NUMBER OF LONGITUDINALS
DEC    .          (0/0)   ACCURACY CRITERION FOR MOM.OF INERTIA
DEC        .      (FT-TONS) BENDING MOMENT SAGGING
DEC        .      (FT-TONS) BENDING MOMENT HOGGING
DEC    .          (FT)    MINIMUM HYDROSTATIC HEAD
DEC        .      (PSI)   ULTIMATE STRENGTH
DEC        .      (PSI)   YIELD STRENGTH IN TENSION
DEC        .      (PSI)   YIELD STRENGTH IN COMPRESSION
DEC            .  (PSI)   YOUNGS MODULUS
DEC        .      (PSI)   SECONDARY BENDING STRESS AT PLATE
END 0

PMD M885-721-PROGRAM
PMR LOC,LOC+1000,FLO,FPR
CLR
PAK
RIP M885-721-DATA-DAVIS
RIP M885-721-INPUT
RIP M885-721-PROGRAM
BGN M885-721-PROGRAM
XPM M885-721-PROGRAM
TER M885-721-PROGRAM
```

Index of Addresses And Their Contents

CONST	0	-1.0	SCANT	0	BEAM DESIGNATION	PLATE	0	lb/ft^2
"	1	1.0	"	1	" "	"	1	t
"	2	2.0	"	2	" "	"	2	t^2
"	3	0.29289	"	3	A_j			
"	4	-0.4292	"	4	c'_j			
"	5	12.0	"	5	I_j			
"	6	40000.0	"	6	I_{jyy}			
"	7	1.70	"	7	blank			
"	8	7.7855	"	8	blank			
"	9	-0.04	"	9	d			
"	10	0.29767						
"	11	-0.02171546						
"	12	1.5708	INPUT	0	D			
"	13	0.8660	"	1	B			
"	14	0.50	"	2	R			
"	15	10414.0	"	3	F			
"	16	0.0127	"	4	W			
"	17	30.0	"	5	a_o, a			
"	18	18.0	"	6	Δa			
"	19	324.0	"	7	a_f			
"	20	54.0	"	8	n_o			
"	21	9.6	"	9	Δn			
"	22	-1.6	"	10	n_f			
"	23	-0.88	"	11	ΔI			
"	24	16970	"	12	M_1^+			
"	25	20.0	"	13	M_1^-			
"	26	1.5	"	14	H_o			
"	27	0.90	"	15	σ_{ULT}			
"	28	1.10	"	16	σ_{yb}			
"	29	2240.0	"	17	σ_{yp}			
"	30	144.0	"	18	E			
"	31	5.0	"	19	σ_2			


PAGE: 114 116 118 120 122 124 126 128 130 132 134 136 138 140 142 144 146 148
TEMP
Θ
λt
Σ A, (SAG) ΔI ΣA ΣA₂⁺
tω
tω Σ cos²Θ/A + Σ z²/I
ΔΘ
λt^3/12
Σ A, (HOG)
ΣA₂⁺z
tf
tf Σ x²/I
sin Θ
λ²t
Σ A₂(SAG) I₁⁺
ΣA₂⁺z²I
D
D
Σ Γ' Ex cosΘ/A - MEx²/I
cos Θ
λ⁻t³/12
Σ A₂(HOG) I₁⁻
ΣA'(z_c - z)
W
W
Σ 1/I
A₂
Σ H sin Θ
(λ - tω)
Σ MEx/I
A₂⁻
Σ [H cos Θ - (c + ω)]
A
t/2
Q
(λ)³t/12
I₀
I
I₂yy
c
I₃yy
c'
c₂'
I/c
c₂'⁻
σA⁻
σB⁻
σB
I₂
I₂⁻
K
+1.0
30tω
60tω
d - c₃' + t/2
A SIDE
n₀
b₀
b₀
b²
b³/12
B/2
½(F - R)
½b₀, ½b
B/2 - R
λ/t
λ
L57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LOC
+1
+2
+3
+4
+5
+6
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+11
+12
+13
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+15
+16
+17
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+22
+23
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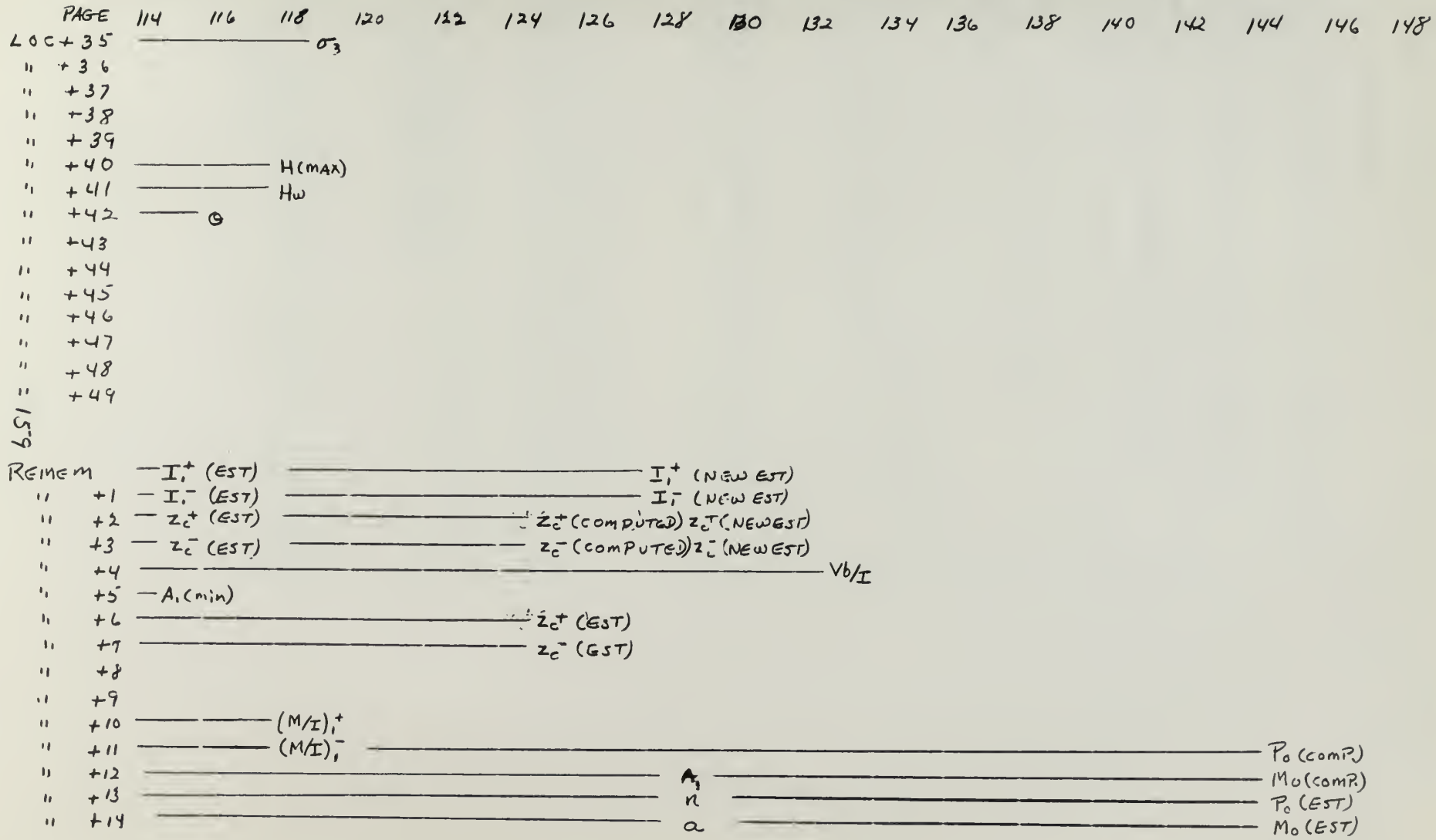
+28
+29
+30
+31
+32
+33
+34
151
c
z
y
BEAM DESIGNATION
BEAM DESIGNATION
BEAM DESIGNATION
a/k (max)
t
σ1+
σ1−
M2
A2+
I2/c (min)
I2/c' (min)
λ−
H (max)
Hw
θ
A2−
I2
I2−
I2yy
I2yy
PLATE DESIGNATION
t
t2
σ1+
σ1−
Pex
Qex
Mex
tw
tf
D
W
A
Q
I
c
c'
H sinθ, H sinθ + S cosθ
H cosθ − (c+ω) − S sinθ
sin θ
cos θ
Q = ΣA(zc − z) S sinθ
S cosθ
P
Q
M
P
Q
M


PAGE
114
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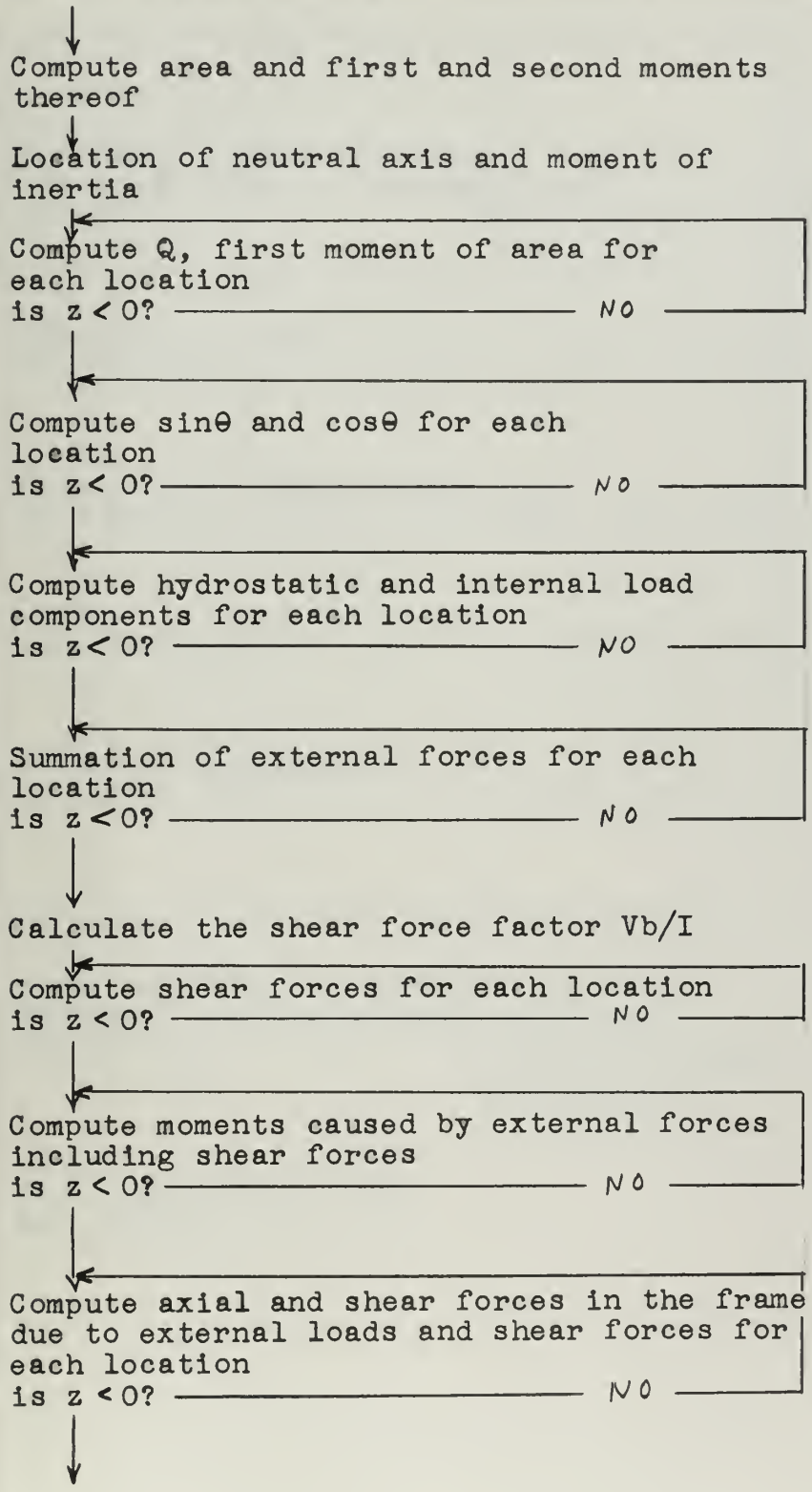
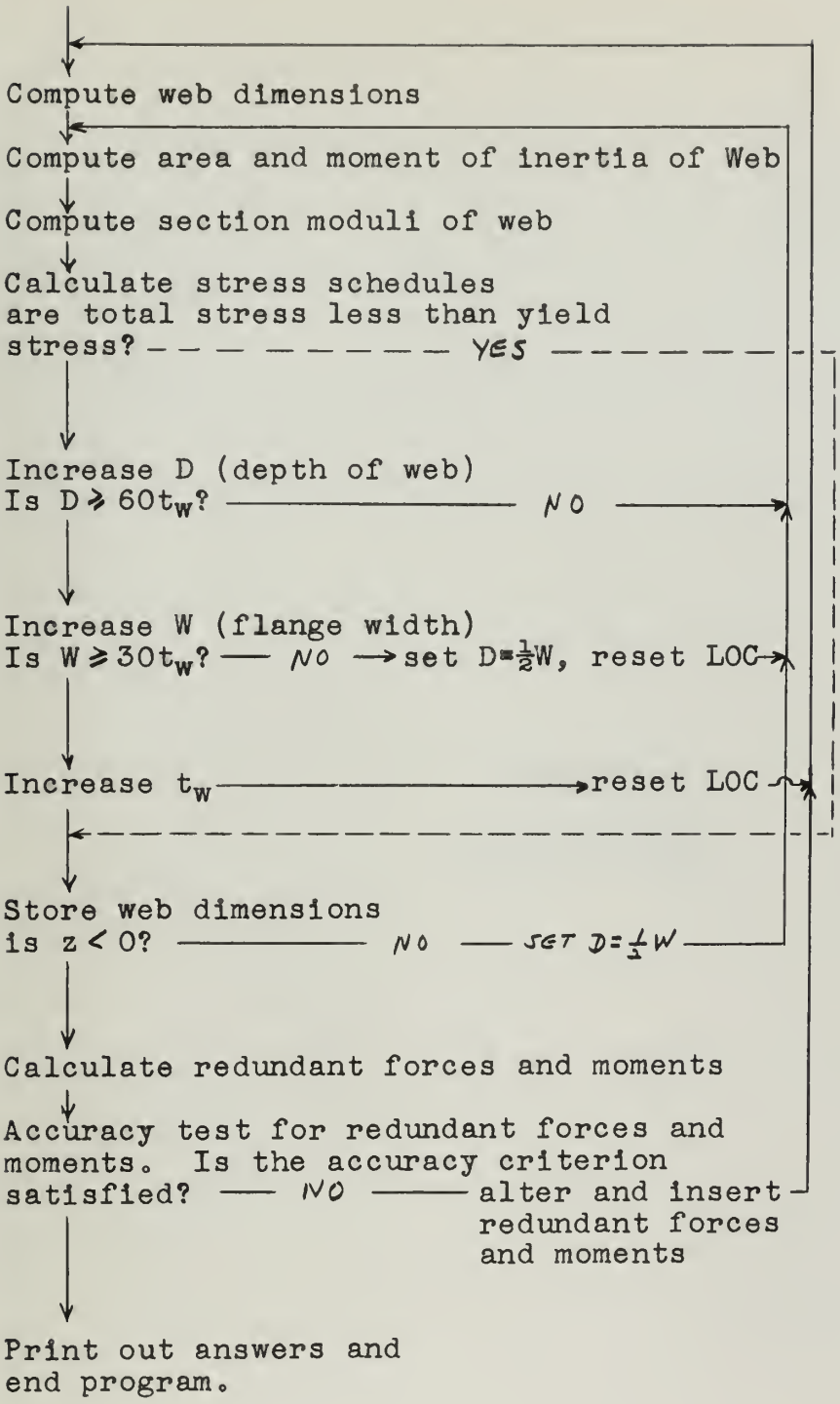
146
148
LOC +35
+36
+37
+38
+39
+40
+41
+42
+43
+44
+45
+46
+47
+48
+49
651
σ_3
H(MAX)
Hω
Θ
REGIME
+1
+2
+3
+4
+5
+6
+7
+8
+9
+10
+11
+12
+13
+14
I_1^+ (EST)
I_1^- (EST)
z_c^+ (EST)
z_c^- (EST)
A_1(min)
$(M/I)_1^+$
$(M/I)_1^-$
I_1^+ (NEW EST)
I_1^- (NEW EST)
$\dot{z}_c^+$ (COMPUTED) z_c^+ (NEW EST)
z_c^- (COMPUTED) z_c^- (NEW EST)
Vb/I
$\dot{z}_c^+$ (EST)
z_c^- (EST)
A_1
n
a
P_0 (COMP.)
M_0 (COMP.)
P_0 (EST)
M_0 (EST)

FLOW DIAGRAM FOR CALCULATION OF WEB FRAME DIMENSIONS

Note: assume that all scantlings and plating have been selected.




Compute web dimensions
Compute area and moment of inertia of Web
Compute section moduli of web
Calculate stress schedules
are total stress less than yield
stress?
YES
Increase D (depth of web)
Is $D \geq 60t_w$?
NO
Increase W (flange width)
Is $W \geq 30t_w$?
NO
set $D=\frac{1}{2}W$, reset LOC
Increase t_w
reset LOC
Store web dimensions
is $z < 0$?
NO
SET $D=\frac{1}{2}W$
Calculate redundant forces and moments
Accuracy test for redundant forces and
moments. Is the accuracy criterion
satisfied?
NO
alter and insert
redundant forces
and moments
Print out answers and
end program.

APPENDIX E

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BIBLIOGRAPHY

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